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GRADUATE SCHOOL

Thesis

THE EUROPEAN CORN BORER

CORRELATION OF THE DEVELOPMENT AND GROWTH OF THE INSECT AND THE CORN PLANT

Submitted by

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B. E. Hodgson

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Outline

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(Footnote to title)

[1] A detailed study of corn as a host of the European corn borer was initiated by D. J. Caffrey in 1919, and was turned over to the writer in 1920. In 1924 the investigations were enlarged through the cooperation of the Massachusetts Agricultural Experiment Station. This larger phase of the work was carried on at The Market Garden Field Station, Waltham, Mass. S. B. Haskell, and later F. J. Sievers, directors of the experiment station, and R. M. Koon, in charge of the field station have shown a genuine interest in the work, and have assisted in many ways, especially by providing ample land, and by furnishing horses, tools, and greenhouse space when needed. P. W. Dempsey, field superintendent of the state station, assisted by drawing the field plans and by taking charge of the planting and care of the corn.

The principal assistants in this work were H. J. Cronin (1926-30), G. W. Still (1926-28), M. J. Sawyer (summers 1925-29), and J. W. Wallace (summers 1926-29). Many others have helped for short periods during the twelve years.

The two main experiment fields were located, one on the Brooks Estate, West Medford (1919-27), and the other at the Market Garden Field Station, Waltham (1924-30). In addition, supplementary fields were maintained at Saugus and Cambridge (1920), Belmont and Woburn (1921), Arlington (1922), and Melrose (1923) - all in Massachusetts. In addition to the work carried on in these fields, more or less detailed observations were made for several years on commercial plantings of sweet corn on several farms of the vicinity.

INTRODUCTION

EXPLANATION OF THE WORK

Corn is by far the most important host plant of the European corn borer in New England. It is the only crop upon which financial loss has occurred commonly and over considerable areas. This is true not only because, among the economic plants, it is the most frequently attacked, but also because it is more generally grown than any other crop which this insect infests. Because of this importance of corn, both as a host and as a crop, most of the observations and experiments have been confined to it.[2]

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[2] For a consideration of the host plants in general see: "D. J. Caffrey, A Progress Report on the Investigations of the European Corn Borer, 155 p., illus., p. 15" and Hodgson, B. E., 1928 - The Host Plants of the European Corn Borer in New England, U.S.D.A. Tech. Bul. 77, 64 p., illus."

The greater part of the infestation in the experimental as well as the commercial plantings was natural, but in some of the experiments on larval establishment, migration, and indirect injury it was necessary to decrease or to increase the number of borers present. The former is accomplished by placing cages over the plants during the height of the oviposition period and by removing egg masses from the plants, and the latter usually by inducing the moths to lay eggs on the plants. This "artificial" oviposition was obtained by confining the moths in small cages attached to the plants in such a way that the eggs were placed where they were desired. (See fig. 1)[3]. This made it possible to locate most of the eggs on the undersides of the lower leaves where they are naturally placed by the moths, or to confine them to definite parts of the leaf or plant, for special experiments. It also made possible daily records of oviposition in a fraction of the time that would have been required if the whole plant or hill had been included by a cage, and it allowed a very good control over the concentration of eggs on the plants. The cages were removed to other leaves as soon as eggs were found in order to leave the eggs in a natural environment. In experiments where large concentrations of borers were desired and no attempt was made to secure data on larval establishment, the eggs, laid on waxed paper[4] in the insectary, were incubated until about ready to hatch, and then placed on the plants.

[3] The cage found best suited for this purpose is made of wire screen cloth, cylindrical in form, about 6" long by 1" in diameter, and closed at one end. The other end, where the leaf is inserted, is closed with a cotton plug. Blotting paper is wrapped around the cage to protect the moths from excessive sunshine or beating rain. If carefully handled, these cages do not injure the plant and they are not left on long enough

(footnote continued)

to retard growth. One man can care for several hundred of them throughout the oviposition season.

[4] This is a method of handling eggs originated by D. W. Jones of the parasite department.

In still other experiments it was necessary to know the approximate number of newly hatched larvae and the time when they started their invasion of the plant. This was accomplished in two ways. The first method was employed when there was no necessity of locating the larvae on any particular part of the plant. In such cases~~,~~ the newly hatched larvae were brought to the plants in two-inch vials. These vials were attached to the plant with an elastic band or a piece of string. A black paper cover on the outside of the container was found of great advantage in hastening the movement of the larvae to the plant. The other method was used when it was essential to obtain the larvae on some particular part of the plant, such as the under side of a leaf. In this case the larvae were brought to the plant in gelatin capsules, which were opened by cutting off one end, and cement~~ing~~ed ~~them~~ to a leaf in the desired place. In both types of containers, the eggs, laid on waxed paper, were partially or entirely incubated in them. The individuals are most easily counted shortly before hatching, when the heads show very definitely through the shells.

The principal data collected were the proportion of plants and ears infested, the amount of grain destroyed, and the larval content of infested plants and ears. In a more limited way data have been collected concerning the number and location of eggs, the parts of the plants and ears attacked, and the reduction in yield. The counts showing percentages of infestation were based on a careful surface examination; those on the amount of grain injury, reduction in yield, and on larval content required the dissection of the plants. In the case of superficial examinations, 100 was usually taken as a unit of sample. When dissections were made, the unit used was usually 10 for whole plants and from 10 to 100 for ears. Occasionally the size of the sample had to be reduced because of a shortage of material, or because of a lack of time. On the other hand, in some of the experiments the sample was much larger. In much of the work, the same kinds of data had to be taken twice because of the presence of two generations.

An endeavor was made to eliminate error and to conduct all comparable experiments as nearly as possible under identical conditions. Series of plots were made the same size; replication was practiced as much as time and space would allow; check plantings were numerous; comparable data were collected at approximately the same time either in respect to the development of the insect or to the growth of the plant. Samples were made by taking plants or hills at random from several parts of the plot. In many of the more detailed experiments every plant was examined thus obviating any process of sampling. Plots were isolated by buffer rows, usually the two outer rows on each side, sometimes more. In cases where there was especial danger of immigrant larvae spoiling the experiment, plowed strips of ground, usually 10 feet wide separated the elements of the experiment. In some cases absorbent barriers of older plants were employed both to hold migrant larvae and to attract undesirable oviposition. In a few, cages were used to prevent natural oviposition.

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An endeavor was made to eliminate error and to conduct all comparable experiments as nearly as possible under identical conditions. Series of plots were made the same size, replication was practiced as much as time and space would allow, check plantings were numerous, comparable data were collected at approximately the same time either in respect to the development of the insect or to the growth of the plant. Samples were made by taking plants or hills at random from several parts of the plot. In many of the more detailed experiments every plant was examined thus obviating any process of sampling. Plots were isolated by buffer rows, usually the two outer rows on each side, sometimes more. In cases where there was especial danger of immigrant larvae spoiling the experiment, plowed strips of ground, usually 12 feet wide separated the elements of the experiment. In some cases absorbent barriers of other plants were employed both to hold emigrant larvae and to attract undesirable oviposition. In a few cages were used to prevent natural oviposition.

THE RELATION OF THE INSECT AND PLANT

A knowledge of the development and nature of an insect's depredations on its host plant, and the suitability of the plant for its guest is of the greatest importance. In this case it involves a study of the seasonal cycle of the insect, oviposition, larval movements and establishment, and location and appearance of the injury - all correlated with the characteristics, development, growth[5], and the condition of the host plant. Information on these subjects aids not only in a determination of the amount of injury inflicted, but also in the employment of control measures, such as liberation of parasites, application of insecticides, selection of an optimum planting date, and methods of destroying the borers in debris.

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5 Throughout this work "development" refers to the formation of new parts, and "growth" refers to the enlargement of these organs, although both phenomena, to a certain extent, are simultaneous.

The relationship of the seasonal history of the borer and of the development and growth of the corn plant is intricate. This is especially true in New England, both because of the complicated seasonal cycle of the insect, and because of the wide range of dates upon which sweet corn, the principal corn crop of this region, is planted. The plants may be at any stage from breaking through the ground to drying up with age when oviposition by the moths, or invasion by the larvae, takes place. Since the plants are comparatively small during May and early June and usually well grown during late July and August, entirely different conditions are presented to the newly hatched larvae of these two periods. Not only is the relationship between the insect and plant often very different, but it is also constantly changing. While the larvae, which at first are barely more than a millimeter in length, are going through their instars and increasing rapidly in size, the plant too is becoming larger and more diversified in structure. The larvae frequently take advantage of this change by moving to the newer organs of the plant.

Both the insect and the plant must be watched throughout the year, particularly during the critical periods in the life of either. Every stage of the insect is hazardous. With the host plant, corn, the greatest reduction in the number of insects takes place during the fall when most of the refuse plants are destroyed (table 2). Probably the next greatest reduction comes between the hatching of the eggs and the time when the first instar larvae have found comparatively safe refuge within protecting parts of the host plant. The plants are in a most susceptible condition throughout the stage of ear development and growth, first, because injury to the leaves or stems at this time may result in a reduction of the number and size of the ears, and second, because the ears are succulent and therefore suitable for direct attack. The most disastrous combinations of insect and plant development are; first, plants large enough to be attractive to the moths of the overwintering generations as oviposition sites, since the resulting larvae will enter the stalks and gradually cause an increased amount of injury in them up to, and through, the period of ear development, and, second, plants that are developing ears at the time when the newly hatched larvae of the second generation[6] are crawling over them in search of protection and food.

[6] This sometimes occurs with the first generation when the corn has been planted extra early.

SUITABILITY OF CORN AS A HOST

The corn plant, as ordinarily grown, makes an excellent, although not perfect, host for this insect. Early sweet corn is in a suitable condition for oviposition by the first flight of moths, late planted sweet corn for the second flight of moths, and field corn and some of the slower growing sweet corns serve both. The vertical arrangement of the leaves of the young plants and, later, the leaf-sheaths and silk of the ears of the older plants make the best of entrance points for the larvae, places where they can find protection and food before they start tunneling into the plant tissues. The plants even when small at the time of egg deposition grow rapidly, more than keeping pace with the development of the larvae. Since the larvae are chiefly internal feeders, they require comparatively large plants, especially in the later instars. Corn supplies this need exceptionally well. Within the main stems, and the protecting leaf and ear-sheaths, there is ample space, except in cases of extremely large populations[7], for all the borers that have become established therein to complete their growth.

[7] Barber, G. W. 1924. Migration - An Important Habit of the European Corn Borer. Jour. Econ. Ent. 17: 582-589, illus.

The corn plant furnishes an abundance of suitable food for the growing larvae. This insect has a comparatively simple digestive system, there being little differentiation of the alimentary tract. It is, therefore, probably dependent upon soft and watery foods. Although small larvae feed freely on the green leaves and in the tassel buds, the larger larvae are rarely found feeding on these parts, and controlled experiments indicate that they require the more succulent plant tissues, either the soft inner parts of leaves and stems, or fresh silk, or soft kernels, in order to obtain their full development. They have been found to thrive and pupate on no other food than the silk or the kernels (table 1). Attempts so far to bring them through on exposed, mature leaf tissue have failed. This, however, may have been caused by the drying up of the leaf sections. Second and third instar larvae, occasionally larger ones, have been seen feeding on such leaf surfaces within cages, and even in the open during protracted periods of cloudy, humid, weather. Although many larvae of the fourth and fifth instars are found feeding on the pith, this part of the plant alone seems poorly suited to their needs; larvae segregated to the pith grow slowly and few pupate (table 1). Most larvae doubtless feed on several kinds of tissue during their development but the bulk of nourishment is furnished by the more tender parts, especially the inner side of the leaf-sheaths, encircling the stalk, the inner ear sheaths, fresh silk, and soft kernels.

Besides serving so well as cover and food during the growing season, the corn plant makes ideal quarters for the hibernating larvae. The stems even when broken into short sections are sufficiently large to protect and carry the insect through this hazardous period of its existence, and stubble is excellent for this purpose(fig. 2). In fact, in real farming sections, away from the weed areas and neglected gardens of urban communities, such material is the principal hiding place of borers that successfully pass the winter. In most of the fields where such debris has been examined, the estimated number of borers present was sufficiently large for the progeny during the ensuing season to be as numerous as during the preceding year, or even reach the maximum numbers that the host plant would support if other factors should be sufficiently favorable. (See table 2.)

The excellent entrance points for larval invasion of the plant have been noted, but there are other less favorable characteristics, especially in certain varieties. Some of the dent corns have a very hard cortex which is not freely entered by the borers. Although the tassel buds, when protected by the leaves, are especially favored by the young larvae, they are soon exposed by the growth of the plant and become dry, causing the borers to leave. Then again, the silk and kernels when succulent make the best of food, but they also change comparatively soon, the silk becoming dead and dry, and the kernels hard, and so frequently cause the larvae to seek other sources of nourishment. Occasionally larvae, especially the smaller ones, and pupae are found dead between the leaf-sheaths and stalks, or between rolled leaves; these may have been squeezed by the swaying of the plants in strong winds.

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This plant, moreover, is not always in a suitable stage of development or condition for the insect's needs. The more quickly maturing varieties of sweet corn are available for only one or the other of the generations. The very early plantings become dry and unattractive to the second brood moths and also would not be highly satisfactory as food for the larvae, and the late plantings are too young, if indeed they have broken through the ground, to be attractive to the first brood moths. Apparently, at times, parts of the plant become too dry to thoroughly serve the needs of the feeding larvae, and they become restless and leave their locations. While there are no figures to support the view, there is indication that during protracted drouths such movements become quite general. These migrations doubtless result in a great deal of mortality. Then there is a high mortality of pre-pupae and pupae of the overwintering borers; this may be the result of the condition of the plant.

SEASONAL CYCLE OF THE INSECT [8]

The corn borer's seasonal history in the two-generation area of eastern New England is further complicated by the presence of both single and two-generation individuals, not as two distinct "strains", but rather as two phases of the same "strain". That is, the progeny of individuals are not consistently one or the other type.[9] Although there is a slight overlapping of the first and of the second generation, the presence of the two broods, while greatly increasing the quantity of data required does not seriously complicate the problems, but the mingling of single-generation individuals, requiring a whole year in which to complete their life cycle, with two-generation individuals, completing two life cycles during the same period of time, does complicate the work, and makes certain problems quite difficult. It is impossible to distinguish with a certainty individuals of the different broods except from the latter part of July, when pupation segregates those destined to produce a second brood, up to about the middle of September, when the larvae of the second brood are becoming full grown and identical in appearance with those which failed to go through the summer pupation. For most of the host plant work, however, it is sufficient to consider those larvae originating from the eggs laid during June and early July and recorded before August as first generation, whether destined to pupate during the summer or not, and those occurring after about the middle of September and through emergence the following June, the "overwintering generation", whether they originated from the first or from the second brood of eggs.

[8] For a discussion of the seasonal cycle of this insect see: Caffrey, D. J. 1927. A Progress Report on the Investigations of the European Corn Borer. U.S.D.A. Bul. 1476, p. 82.

[9] Barber, G. W. 1925. Remarks on the Number of Generations of the European Corn Borer in America. Jour. Econ. Ent. 18:496-502.

There is a tendency for early emerging moths to give rise to two-generation, and late emerging moths to single-generation individuals. This has been noted in the insectary, in the experiment field, and in commercial plantings. An insectary experiment was made in 1926, involving about 50 larvae reared from early eggs and an equal number from late eggs, all laid by moths from overwintering larvae. Most of the early group pupated that summer; all of the late group failed to pupate although they became large, normal larvae. This experiment was repeated later on a larger scale and in the open. Oviposition was procured on one plot from the earliest moths available, and on another from the latest. Unfortunately the season was not favorable for a second generation, hence even the earlier laid eggs showed a majority of single-generation individuals, but not so large a proportion as did the later (table 3).

This complication of generations is involved with the amount of injury inflicted on corn planted on different dates. In extra early plantings there is a tendency for a large proportion of the borers to be first generation and in plantings made a little later, single-generation. Late corn, except where migration enters in, is attacked only by the second generation, and mid-season corn often escapes severe injury by either brood. Larvae of the first brood are generally normal in size, but those of the second brood tend to be under-sized[10] and also have frequently not reached the fifth instar when the corn is picked. This results in a smaller amount of plant destruction and crop loss per borer on late than on early corn. The relative abundance of individuals of the two generations varies greatly from year to year, but as a rule the second generation is much larger than the first.[11] This difference in numbers can best be seen by comparing the figures of the April 26 and of the June 20 plantings of Golden Bantam and of Black Mexican sweet corn in tables 21 and 22; the first plantings were attacked only by the first brood, and the last plantings, with the possible exception of a few migrants, were attacked only by the second brood. It is this great increase in numbers of larvae late in the season that is largely responsible for the severe injury inflicted on late sweet corn. Evidently, then, a consideration of the generations is of vital importance in the study of extent of injury and effect of planting date.

[10]Barber, G. W. 1925. Remarks on the Number of Generations of the European Corn Borer in America. Jour. Econ. Ent. 18: 496-502.

[11]Hodgson, B. E. 1928. The Host Plants of the European Corn Borer in New England. U.S.D.A. Tech. Bul. 77, 64 p., illus., p. 37.

Although the egg and larval stages show the more important differences in the relations of the two broods to the corn plant, it is interesting to note the status of the pupae and adults. Pupae of the first generation are found in the growing plant, usually in the stalks or ears (fig. 3), but occasionally on the surface of the plant (fig. 4). But pupae of the overwintering brood are found in an entirely different environment, the dry stalks and stubble. The adults probably visit the plants only for the purpose of oviposition; during the day they are usually found in the grass and low weed growths. Since this is the case, there is little more to add concerning the moths than has already been mentioned in regards to oviposition. It might be noted, however, that the plants normally are in a more attractive stage of growth during the second flight (first generation moths). In field cages containing corn plants, this brood is very troublesome in laying eggs on the outside of the cages, apparently in an effort to reach the enclosed plants.

OVIPOSITION AND LARVAL ESTABLISHMENT

FIRST GENERATION

The first oviposition period occurs at a time when the corn plants vary in size, depending on the season and the time of planting, from those barely breaking through the ground to those from one to two feet tall with a considerable amount of leaf area. In fact, some corn has not yet sprouted and the most advanced is only starting to show tassels at the end of this oviposition period. There is a great variation in the number of eggs laid on these different sized plants, the greater number being laid on the larger plants. ~~(See the discussion on comparisons of infestation of corn planted on different dates.)~~ The eggs are found almost invariably on the undersides of the lower leaves of the plant, and are usually placed toward their proximal ends. Of 108 egg masses recorded as to position, 75 were on the proximal-third, 20 on the mid-third, and only 13 on the distal-third of a leaf; over 50 per cent were on the first two leaves of the plants; and only 3 were on the upper side of a leaf (table 4).

Where the eggs are laid seems to have little bearing on what parts of the plant are first invaded. Hatching larvae may feed a little on the leaf-tissue beneath the egg mass, but such injury is not noticeable and is of no consequence if it does exist. It may be that there is little feeding done for several hours after hatching, since the alimentary tract is filled with yolk, which could serve for some time. Laboratory experiments have shown that under a favorable temperature and humidity environment, larvae isolated at the time of hatching, live between one and two days, some longer, without food. Of 110 larvae, 7 died the first day after hatching, 36 the second, 65 the third, and the remaining 2 the fourth day(table 5). The newly hatched larvae mill about for a time on the egg mass, but soon scatter and crawl over the whole plant and other plants of the hill; and some find their way to other hills in the vicinity.

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Eventually most of the little larvae that remain on the plant, or gain other plants, descend into the vortical part and begin feeding there on the tender, partially protected leaf tissue, usually from the upper-side, or if the plants are sufficiently advanced, into the tassel buds, which are yet more or less concealed by the rolled up leaves. The larvae do not go directly into the heart of the plant, but work their way down gradually as the plant unfolds, remaining through the first and second instars about the point on the leaf or tassel where it is separating from the tightly appressed condition. In scores of plants, dissected at varying intervals after invasion, very few of the small larvae are found in the bleached inner portions of the plant. The feeding is done well out of sight, however, the injury only becoming conspicuous a few days later as the growing plant exposes it. By the time the leaf injury appears, the larvae are farther down in the plant, have cut through the rolled leaves to the developing tassel, if they are not already there, or are actually beginning to tunnel into the tender stems and leaf-ribs. They begin to tunnel during the third and fourth instars. (See table 6; notice especially experiment C and footnotes 3 to 5 of experiment A, and table ~~18~~ 20)

SECOND GENERATION

Second generation eggs are laid at a time when most of the plants have at least reached the stage of inflorescence. Like the earlier brood of eggs they are laid most often on the under-side of the leaves, toward their proximal end, but the leaves are so long now that the eggs are frequently a foot or more from the stalk. A considerable number, however, are laid at the base of the leaf. There is a tendency for the eggs to be relatively higher in the plant, the leaves of the central and even the upper parts being freely used as oviposition sites. Not infrequently egg masses of the second brood are placed on the leaf-blades occurring toward the tips of the ears. This ear-foliage is much larger on some varieties than others, so that in certain ones, such as Golden Bantam, there are many masses laid on this part of the ear, while in others, especially some of the dent corns, this type of foliage is practically absent, and therefore receives few or no eggs. Only rarely are eggs placed on the stalks or the upper-side of foliage. An examination of 50 plants of Country Gentleman sweet corn on August 26, 1921, for location of egg masses showed 37 on lower leaves, 78 on central leaves, 42 on upper leaves, 29 on ear-foliage, and 5 on stalks. In 1927, examinations throughout the second generation oviposition season revealed on 75 plants of Longfellow flint corn, 57 egg masses on stalk-foliage and 5 on ear-foliage, and on 75 plants of Northwestern dent corn, 15 on stalk-foliage and 3 on ear-foliage. More detailed records of the location of egg masses was made in 1928 on 100 plants of Golden Bantam sweet corn and 50 plants of Pride of the North dent corn. This work revealed the same tendency for oviposition to take place well up in the plant. The ear-foliage of Golden Bantam received 30 per cent of the eggs laid on this variety and the same location for the dent corn received only 5 per cent. Of the 228 masses found on the stalk leaves, 112 were

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on the proximal-third of the leaves and 44 of these were actually at the base of the leaf, indicating a decided tendency for the moths to lay near the stalk. Only one mass was ~~actually~~ placed on the stalk, and only one on a leaf-sheath. (See table 7.)

The newly hatched larvae of the second generation, like those of the first, show a decided tendency to wander over the plant before starting to feed; in fact, shelter rather than food seems to be sought. The infestations are not centered near where the eggs are laid. The differences in the place of oviposition or of invasion of the plant by the second generation are entirely caused by the differences in the plant at this later period. On very late planted corn, furnishing plants comparable in size with those used by the first brood of moths, the infestation is identical with the earlier one.

But as most of the plants are nearly grown, there is no longer a roll of unfolding leaves, surrounding tender, growing tassel buds as was the case at the time of the earlier invasion. The plants have now "spindled" out, and in place of the former central harbor, there are numerous excellent points of entrance, the leaf-sheaths, and the ends of the ears. Most of the larvae soon pass into these parts of the plant. The leaf-sheaths, encircling as they do the stalk and extending almost from the node of their origin to the next node above, form natural pockets or envelopes which protect the larvae while they feed on the inner surface of the sheath and before they are large enough to start tunneling into the stalk (fig. 5). The ends of the ears, both the ear-sheaths and the silk, especially the latter, form equally easy entrances to the ears.

Not all the larvae take these easy paths into the plant. Some enter the mid-ribs of the leaves, usually from the upper-surface and close to the plant (fig. 6). They may remain in the leaf-ribs for some time, but this location is abandoned before the larvae become full grown, except in rare cases. Many of the borers cut through the sheaths, and some enter the tassel-stem or other exposed points on the stalk; it is probable that these entrances are made by migrant larvae that have reached a considerable development in some other location. Most of those passing between the ear-sheaths reach the kernels, but a very few pass clear down to the shank. Entrance of the shank by tunneling through from the main stalk practically does not occur. Of 762 larvae found in the ears (including the shanks), only one is recorded as having entered this way. The structure of the plant would account for this. At the point where the ear-branch joins the main stem, it is small and fibrous. It thus offers a very narrow passage of rather tough, resistant tissue. (See table 8.)

Some of the borers start to tunnel into the stems in the third instar, but probably most of them are in the fourth, and many even in the fifth instar before they actually penetrate the stem cortex. Some even complete their development within the leaf-sheaths. This is most likely to be the case in the large, hard-stemmed dent corns. By far the larger number enter the plant stems from the protecting leaf-sheaths where they spent their early instars, but many, probably migrants, cut through from the outside of the plant. The stem is more frequently entered at a node than at an internode. It seems rather strange that the nodes, which comprise a relatively small part of the surface of the stem should be more freely attacked. Possibly the explanation is that the junction of the sheath and blade of the leaf, where invasion most frequently takes place, is approximately opposite a node. In the case of the ear invasion there is no sharp distinction between surface feeding and tunneling. The little larvae feeding on the silk gradually work their way into the tip of the ear. This entrance is most quickly made in ears where the cob is long and extends close to the ends of the sheaths or even beyond them. Under such conditions very small larvae are commonly seen tunneling into the soft cob. In cases where the sheaths are long and tightly appressed at the end, the entrance is not made so readily. In fact, larvae seem to have the same reluctance for entering such ears as they do for penetrating stems. Not infrequently when only one or two larvae are present in the silk, they complete their growth without leaving it.

The larvae having entered the stem, usually at or directly above a node, at first work upward (fig. 7). They make a rather irregular tunnel and often excavate most of the pith in the region of the entrance hole. When the entrance is made between nodes, the tunnel may extend either up or down, or in both directions. It is rather infrequent that a larva enters the stem directly below a node. When it does it usually works downward away from the node. Although the partly grown larvae do not ordinarily pass through the nodes, such behavior is not uncommon even when there is no apparent reason for it. As the borers become full grown there is an increasing tendency for them to work down ~~ward~~ as well as up and to pass through the nodes ~~(fig. 6)~~.

Many varieties of corn have large rudimentary as well as developed ears. These ears, although lacking kernels, have cob, sheaths, and silk sometimes little inferior in size and quantity to those of the real ears. While infestation in such ears has usually merely been considered a part of that of the stalk, they should be considered as ears when studying invasion, because, from the standpoint of invasion, they are practically identical with the ears. In order to make sure of the similarity of attack on these two conditions of ear development, a few of each were dissected. The figures from this work indicate that the invasion is quite similar and that the ears, in spite of their greater size, have only a slightly greater total number of borers (table 9). In table 8 the first two groups include rudimentary ears and the last two exclude them. In table 22 there are also figures showing the number of larvae in rudimentary ears and in true ears.

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The central part of the plants is most freely invaded. The third to the seventh internodes from the top inclusive contained about a third of the larvae found in the stalks of 474 plants dissected early in October, 1927 (table 8, second part). Since the ears occur within this region of the plant, the larvae found in them should also be included. This means that most of the larvae in the plants are in the central part. This appears to be in direct correlation with the location of the eggs (table 7). Experiments D and E reported in table 10 seem to bear this out. The plants of these two experiments that had the oviposition high in the plant contained 592 larvae in the upper parts against 554 in the lower parts, and those that had the oviposition low in the plant contained 640 larvae in the lower part against 544 in the upper parts. This tendency is so small, however, that the statement stands that the larvae wander all over the plants and do not center their attack near where the eggs are laid.

The occurrence of eggs on the ear-foliage is probably of no great significance even in the case of those varieties which show a considerable proportion of the eggs so located. Experiments indicate that such oviposition has a slight tendency to result in a larger proportion of larvae invading the ears than is the case when the eggs are laid on the stem foliage, but a surprisingly large number of larvae hatching on the ear-foliage find their way to the leaf-sheaths on the stalks. (See table 10.) Experiment A was concerned with natural infestation. The plants are grouped according to where the eggs were laid. The first group was of plants which had eggs on the stalk-foliage only, the second on the ear-foliage only, the third (see footnote to table 10) on both stalk and ear-foliage, and the fourth group no eggs. The proportions of larvae recovered in the ears of these groups, respectively, were 58, 57, 52, and 52 per cent. In experiment B, 73 per cent of the larvae were recovered in the ears of the plants when eggs had been placed on the stalk-foliage, and only 65 per cent in the ears of the plants where the eggs were on the ear-foliage. The figures for experiment D were equal for both groups of plants, and the figures for C and E favor ear-foliage oviposition. The total figures of all the experiments reported in table 10 give 40 % larvae in the ears of plants which had eggs only on stem-foliage and 47 % larvae in the ears of plants which had eggs only on the ear-foliage. While this indicates that ear-foliage oviposition tends to increase ear infestation, it also shows that a majority of the larvae from such oviposition leave the ears, and are found in the leaf-sheaths and stalks.

THE SURVIVAL OF BORERS

The corn borer, in common with most insects, has a tremendous potential increase in numbers. The reduction of numbers and some of the causes have been studied from various angles; these studies cover every stage of the insect and every branch of the investigations; they include both the natural and the artificially induced reductions. This discussion is confined to the phase of the study most intimately related with the growing corn plant, namely the survival of borers from the first invasion of the plant up to and including the full grown larvae. The number of eggs deposited on the plants, or the number of newly hatched larvae placed on the plants, has been used as a ~~bade~~ base for survival figures, and the expression "larval establishment" has been used to designate the proportion of larvae found in the plant at any particular time of examination, i. e. first instar, 10 days later, full grown larvae.

Because of the priority of other investigations and the large amount of close observations in this work not much has been accomplished in it yet. In order to be comparatively sure of the results, the plants should be carefully examined for eggs at least once in 5 days and preferably 2 or 3 times a week. This is necessary because egg masses might be dislodged before they are seen, or in hot weather they may be laid, hatch, and all traces removed in less than a week. While insufficient data have been collected to justify any statement as to a normal or average larval establishment, a few counts have been made over a period of several years for both generations and including the 3 principal types of corn, sweet, flint, and dent. These data were taken to show the per cent of establishment when the larvae were full grown. Many of them are probably too high because the plants were not always examined as frequently as they should have been and because egg masses are more easily overlooked than are the larvae. (See table 11.)

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Several deductions from these figures are here presented, but they are questionable because the differences in establishment could easily fall within the limits of experimental error. A comparison of the 3 types of corn shows the establishment to be higher in sweet than in flint or dent corn. Of the 11 series where sweet corn was examined at the same time and place with one or both of the other types, 7 show the highest establishment on sweet corn, and in 3 others it is tied for high place. This seems reasonable because of the bushier growth of this type, and, in the second generation, because it was planted later and was therefore in a fresher condition. There appears to be a slightly better establishment for the second generation in spite of the heavy egg parasitism late in the season. The data are insufficient to draw any conclusions as to yearly variations in establishment.

There is an extremely low rate of establishment in the artificially infested plots. This may be caused in part by the greater concentration of borers, but it is most likely the result of emigration from these plots of high borer concentration with no reciprocal immigration. That is, an equal movement in both directions cannot be assumed as it is in the case of natural infestation, for in these cases there is a much lower concentration of borers in the surrounding plants. The study of migration is closely connected with that of larval establishment. A reduction of the number of borers established in a plant as the season advances may be the result of migration as well as of mortality. Then again, the movement of larvae away from the hills upon which eggs have been laid may result in a comparatively low rate of establishment on those hills, but a high rate when all the plants in the vicinity are considered. It is also possible to have an influx of borers which could make establishment figures too high.

Little is known about the relative importance of the different agencies which reduce larval establishment. The eggs may fail to hatch; they may be dislodged by wind or rain and so destroyed; they may become too dry, or exposed to direct sunlight, which quickly kills them[12]; they may be parasitized. Sometimes egg masses are found which appear as if they had been infected with a disease. Red mites are commonly found feeding on the contents of the eggs. Of all these hazards to which the egg is subject, parasitism by Trichogramma is the only one about which much is known. This species starts its work during the second generation oviposition period, there being only a negligible number of eggs parasitized by it during the first generation. Late in the year, however, it is not uncommon to find from 75 to 90 per cent of the eggs destroyed by it. Records on survival through the egg stage run from 46 to 94 per cent, with an average of 87 for the first generation and 68 for the second (table 12).

As with the eggs, there are a great many agencies acting to reduce the numbers of larvae. There are a number of parasites and at times disease seems to be quite prevalent. Predaceous insects destroy a great many[13]. Cannibalism is quite common among larvae in the insectary and probably accounts for some loss under field conditions. Even in fairly heavy infestations there is a tendency for only one larva to become established in an internode; in a total of 1104 larvae (table 8) there were only 49 cases where there were more than one in an internode. This condition may result from cannibalism. On the other hand, it may entirely result from a strong inclination to segregation. There are indications that some may be injured mechanically within the plant. Although a great deal of mortality takes place within the plant from one cause or another, there is probably more taking place among migrating larvae. It is hoped that these sources of reduction in numbers can eventually be estimated.

[12] Caffrey, D. J. 1927. A Progress Report on the Investigations of the European Corn Borer. U.S.D.A. Bul. 1476, 155 p., illus., p. 91.

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[12] [illegible]

(footnotes for preceding page, continued)

[13] Caffrey, D. J. 1927. A Progress Report on the Investigations of the European Corn Borer. U.S.D.A. Bul. 1476, 155 p., illus., p. 140, and

Barber, G. W. 1926. Some Factors Responsible for the Decrease of the European Corn Borer in New England 1923 and 1924. Ecology 7: 143-162.

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Losses in the larval stage are greater than those in the egg stage. Without doubt the greatest loss occurs during the first instar. A great many of the newly hatched larvae fail to reach a refuge in protecting parts of the plant. Many of these are blown off by the wind, and a surprisingly large number seem to voluntarily leave the plant. While many of these migrant larvae reach other plants, many others must perish. In experiments where plants were artificially infested with a known number of newly hatched larvae, the greatest loss in every case was found to have occurred during the first 24 hours and from then to the thirtieth day it was very gradual. The principal figures in the three experiments recorded are, one day after placing the larvae, 37, 17, and 7.5 per cent establishment and 30 days after starting the experiment the figures were respectively 10, 5, and 3 per cent establishment. (See table 6.)

There are other factors which, although they cannot strictly be considered agencies reducing larval establishment, have an effect on survival. An experiment designed to show the effect of larval concentrations on the degree of establishment indicated that within the limits used, 12 larvae per hill as a minimum and 500 per hill as a maximum, there was no significant difference in establishment (table 13). This was an establishment record at 8 days after setting the larvae, planned as part of a cannibalism experiment. It is likely that an examination made when the larvae reached the fifth instar would show a contrast of figures in favor of the smaller concentrations. As already stated, the low establishment which occurred on artificially infested plots (table 11) may have been the result of an extra heavy concentration of larvae. It seems reasonable that there would be a lowering of the establishment as the density of the borers increased beyond a certain point.

The parts of the plant entered has an effect on the per cent of establishment. Only one experiment has been tried to show this, but it is quite conclusive. A known number of newly hatched larvae were placed on 12 nodes (including a sheath and internode) and on 12 ears, all isolated to prevent migration. The dissections were made of 2 stalk sections and 2 ears on 6 consecutive dates, 3, 6, 10, 15, 21, and 30 days after setting the larvae. In each of these dissections the establishment was significantly larger for the ears. The total figures for the 6 dissections are 22 per cent establishment for the stalk sections and 53 per cent for the ears. (See table 14.)

It is probable that larval establishment becomes higher as the season advances, at least until the latter part of the summer. It has already been noted that second generation establishment is higher than first generation in spite of severe parasitism late in the season. In the experiment on number of generations (table 3) the establishment was only 3 per cent from 6305 eggs laid between June 11 and 30 and was 14 per cent from 8590 eggs laid between July 14 and 26. This better establishment may be the result of more favorable weather. It may also be the result of the more advanced growth of the plants. If this latter is the case it is involved with parts of the plant invaded, discussed in the preceding paragraph.

LARVAL MIGRATIONS

A knowledge of migration is extremely important in several phases of corn borer investigations. Although the movements of the larvae are understood in a general way, there are few facts actually known. The general dispersal of newly hatched larvae over the hills where the eggs were laid and to other hills close-at-hand is obvious. The extensive emigrations of larger larvae from overcrowded plants, and the general unrest and tendency to locate lower in the plants late in the season has been noted by many observers. The less conspicuous movements of borers throughout the season are not fully appreciated. Nor have the causes of migration been fully determined. The few experiments planned to throw light on this subject are not conclusive, and in one case the result was apparently a contradiction of previous work. It is probable that many experiments, such as the comparison of types and varieties of corn, and corn planted on different dates, have been seriously interfered with at times by migration in spite of the intervention of buffer rows or plowed strips of ground.

It has been noted that newly hatched larvae crawl freely over the adjacent plants in a hill before settling down. It is reasonable to expect that this would result in an equal infestation of all the plants. An experiment was planned on 75 hills of each of the three types of corn, sweet, flint, and dent, to determine this point. Obviously, only the hills which showed oviposition on part of the plants could be considered. That is, those hills which showed either no eggs or eggs on every plant were useless. The results of this work indicate that, although the larvae tended to disperse over the entire hill, there was a slightly greater number of borers on the plants upon which the eggs had hatched. The average number of borers per plant were for the first generation 1.6 on the plants where borers had hatched and 1.0 for the remaining plants of the same hills, and the corresponding figures for the second generation were 7.6 and 6.9. All figures throughout the table show this tendency to a greater infestation on the plants where the borers hatched, but, actually, the most important fact revealed is that the infestation was approximately as severe on the plants that received no eggs as upon those that did. (See table 15.)

Early in the investigations, it was observed that there took place a considerable dispersion of larvae from the hills where the eggs were laid to other hills. In 1920 an attempt was made to keep a square block of 16 hills, situated in the center of a small plot of rather heavily infested corn, free from borers by the use of a ground barrier, and the removal of egg masses. It was found impossible to keep all the young larvae out in this way. Then again, in 1927, when a row of sweet corn was artificially infested with a large number of eggs, the two adjacent rows became badly infested, and even the next rows to these showed more injury than did the remaining rows of the plot. An experiment showing the extent of inter-hill migration was made in conjunction with the larval establishment work of 1928. This experiment showed that about three-fourths of the surviving larvae remained on the hills where the eggs had hatched. In the first generation the average number of larvae per hill was 4.0 where eggs had hatched and 0.87 where no eggs had hatched, and the corresponding figures for the second were 16.5 and 4.2 (table 16). These figures do not show what proportion of the newly hatched borers dispersed from the plants of their origin; they do indicate that a majority of the surviving borers are found on the hills where they hatched. The ratio, to be sure, would vary in different environments and at different times.

An important attribute of migration is the distance that larvae attain before becoming established in other hills. With the artificially infested corn, already mentioned, and in similar cases, the bulk of the migration was confined to adjoining hills or rows. Only two experiments have been made to determine this point, and they are contradictory. In the first blocks of 25 hills, forming squares with 5 hills on a side, were used. There were 9 of these blocks; 3 served as checks and 6 were artificially infested with eggs in the central row. In every case the largest average number of larvae per hill ~~were~~ was recovered in these infested rows, about half as many in the adjacent rows, and somewhat less in the remaining two rows (table 17). In the other experiment, blocks of 100 hills, forming squares of 10 hills on a side, were used. There were 3 of these blocks, and 1000 newly hatched larvae were placed on the 4 central hills of each so that they could migrate a distance of 4 hills in any direction from the center. In the first only 8 larvae were recovered in the 4 originally infested hills and the 174 on the other hills of the block were scattered indiscriminately over them. The other 2 blocks showed a similar condition. That is, in every case, most of the recovered larvae had left the plants upon which they were placed, and there was no tendency for them to be confined to adjacent hills (table 18). The opposite results obtained in these 2 experiments may have been because eggs were used in the first and larvae in the second. Or it may have been some climatic or environmental factor, since the experiments were conducted in 2 different years and places.

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There is more or less movement of larvae throughout the season. This has been noticed especially in planting date studies. Plantings made after the middle of May receive very few first generation eggs, and the evidence of invasion by first instar larvae, namely the feeding areas on the leaves, is rather rare, but later, when the harvest examination is made, there is sometimes considerable infestation. This can be attributed only to a migration of partly grown larvae from earlier planted corn close-at-hand.

Several experiments have been planned to measure this gradual migration throughout the season, but time has allowed only one small test to be made. In this experiment, 1000 newly hatched larvae were set on 10 hills, 100 on each. Five of these hills and the 16 hills, forming a rectangle around them, were dissected 5 days later. The other similar group was dissected 20 days later. In the first group 85 per cent of the larvae recovered were on the artificially infested plants and 15 per cent were on the surrounding 16 hills. In the second group, 69 per cent were on the infested hills and 31 per cent on the surrounding hills(table 19). This experiment is unquestionably imperfect. It does not show the migration that failed to reach the 16 surrounding hills. Also, since the larval establishment was much lower on the 20-day group, there is no proof that the 31 per cent migrants really shows an increased amount of migration over the 15 per cent migrants on the earlier date. It will be necessary to experiment further before definite conclusions can be made.

The migration that takes place throughout the season is closely tied up with movements from one part of the plant to another. The presence of first generation larvae in the ears of sweet corn results from this movement, for the ears have not yet developed when the plants are first invaded. Then, when the ears begin to harden, there is a movement from the ears to the stalks. At times, especially when the stalks are drying, or late in the fall, there is restlessness which results in the larvae reaching lower points in the plants. Some of them finally, late in the season, reach the bases of the stalks below the soil level ~~(fig.)~~. Some of this movement takes place within the stalks, but the greater part of it, all of it from the ears, is an external migration, and frequently results in the larvae reaching other plants or hills.

LOCATION, NATURE, AND APPEARANCE OF INJURY [14]

The corn plant is attacked freely by the borer in leaves, stems, tassels, and ears. Although considerable feeding has sometimes been done on the leaves and tassels, the real damage to the plants results from infestation in the stalks, because of its effect on the number and weight of the ears, and from direct injury to the ears. It is the injury to either or both of these parts of the plant, stalks and ears, that has made the borer a serious pest, and for this reason most of the data concerning parts of the plant infested have been confined to them.

14 General discussions have already been published on these subjects (see Caffrey, D. J. 1927. A Progress Report on the Investigations of the European Corn Borer, U. S.D. A. Bul. 1476, 155 p., illus., and Hodgson, B. E. 1928. The Host Plants of the European Corn Borer in New England, U. S. D. A. Tech. Bul. 77, 64 p., illus.). They are considered here for the sake of unity and in order to develop some points not previously covered.

A study of the parts of the plant infested must take into consideration movements of the larvae, for the location of infestation varies with the development of the plant and insect, and the date of examination. At one time all the larvae are in the leaf tissues or tassel buds, at another they are largely in the stems, and at still another many are in the ears. It is evident, then, that data showing the number of larvae in different parts of the plant is good only for the particular time it was made and that complete data on the parts of the plant having injury, can only be had at the end of the season. For examples of this changing condition note the tendency away from the outer parts of the leaves to the inner parts as the season advances (table 6, experiment C). This is even more clearly brought out in table 20 where the July 12 dissection revealed a majority of the larvae in the leaves and tassel buds, and the July 26 dissection, a majority in the stems, and parts of the ears. The great variation in the relative infestation of stalks and ears examined at the same time, but selected from corn planted on different dates, should also be noted (tables 21 and 22). In this case the variation is not the result of a difference in the insect's development, as were the previous ones cited, but was caused by a difference in the growth of the plant. Note, for example, the Golden Bantam sweet corn (table 21). In the April 26 planting there were only 9 plants with ear infestation and 52, or roughly 6 times as many, with stalk infestation, and in the June 20 planting there were 125 with ear infestation and only 113 with stalk infestation. The corresponding figures showing larval content (table 22) are in about the same ratio.

This direct correlation of number of borers and amount of injury, however, does not always hold. Often the damage is much greater than the number of borers remaining could inflict. When corn from the same plot is harvested on 2 different dates, one early and the other late in the season, the ears are sometimes found to have a greater amount of injury and a lower larval content at the second examination. The records on 100 ears selected at random on each of 2 dates, September 27 and October 28, 1924, from a plot of Longfellow flint corn show, for the earlier examination 94 infested with an average of 5.5 and maximum of 36 per cent grain destroyed, and an average number of 4.3 and a maximum of 20 larvae per ear, and for the later examination 90 infested with an average of 6.7 and maximum of 47 per cent grain destroyed, and an average number of 2.1 and a maximum of 9 larvae per ear. On the other hand, certain plants, or plant parts, may show concentrations of borers out of proportion to the injury found.

LEAVES

The earliest injury to the plant is inflicted on the leaves by the first instar larvae, which consume small areas of the leaf tissue, as they work down into the plant. Later, holes are tunneled through the leaves while they are still rolled in the growing point of the plant. These two types of leaf feeding destroy only a negligible amount of the leaf surface. There are two other types of leaf injury which are less conspicuous, but more important. One is the injury to the mid-ribs of leaves, causing them to break over near the stalk. The other is the injury to the inner-side of the leaf-sheaths so common during second generation invasion.

There are few records showing the frequency of the early leaf-blade injury. These feeding areas are sometimes found on plants which later contain no larvae, but more often the later stalk and ear infestations are found on a larger number of plants than ~~was~~ were the early feeding areas. In tables 15 and 16 are figures comparing leaf-feeding with later stalk infestation. The extent to which leaf-sheaths are infested is shown in table 8. Leaf-sheath injury is not so prevalent during first generation infestation, as is indicated in table 6, experiment C, and table 20. There are few records of leaf-rib injury; the principal ones are those given in table 8, which are incomplete. The figures in this table show leaf-rib injury to be about one-third as frequent as that of the leaf-sheaths.

The leaf-blade injury has a very characteristic appearance. An infested plant will show anywhere from a few to several dozen feeding areas, varyimg in size from mere spots to patches an inch long. The smaller ones are most likely to be rounded or somewhat oblong; the larger ones are more likely to be irregular in outline and often long and narrow (fig. 8). They are commonly accompanied by a small amount of powdery-fine frass. Most of these feeding areas do not extend entirely through the leaf; the epidermis on one side is left intact, giving the appearance of a little window. Fibro-vascular bundles, when passing through these areas, are left untouched. Sometimes there is a minute round hole cut through the exposed epidermis, indicating that the larva probably passed through the leaf (fig. 9). It is usually the epidermis of the under-side of the leaf which remains, indicating that the larvae feed from the upper leaf-surface for the most part. At the time the feeding took place, however, it was not the upper, but rather, the inner side of the leaf, which was still in a vertical position. The tunneling through the rolled leaves by

partly grown larvae sometimes results in rows of holes across the leaves (fig. 10). The injury to the leaf-ribs is hardly noticeable except as it causes leaves to break over. The injury within the leaf-sheaths is only seen on dissection, and is described under stalk injury.

STEMS

The main stalks, suckers, and ear-branches[15], constituting the stems of the plant are the parts most frequently attacked. The larvae do not tunnel into the stems until the third or fourth instar, but they gain the greatest part of their size and weight in the later instars (fourth, and fifth), and obviously make the greatest inroads in the plant tissue during these times. Figures showing the comparative infestation in stalks and other parts of the plant are given in tables 7, 8, 20, 21, 22 and 24. The few figures available, showing the extent of infestation in the suckers, indicate that they are not as badly infested as are the main stalks. The principal data on relative number of suckers and stalks and the larvae in them are given in table 22. The effect of infestation in the stalks and suckers is more far-reaching than the mere injury to these stems themselves. It interferes with the vascular system, hindering both the free flow of solutes from the soil to the chlorenchyma of stems and foliage, and the translocation of food or food material from this chlorophyll bearing tissue, where it is elaborated, to the parts of the plant where it is used or stored.

[15] That part of the ear-stem which is ordinarily broken off with the ear is here considered the shank, and the remainder of the ear-stem, which varies from a few inches to a foot long, or even longer, is considered the ear-branch.

Some work has been done to show the extent of infestation in different parts of the main stalk. It is simpler to consider the tassel as a part of this main axis than to treat it separately. The early feeding in the tassel buds by first generation larvae has already been discussed. The extent of this feeding is seen in table 6, experiment A, and table 20. This feeding, although highly important in the establishment of first instar larvae has an insignificant effect on the plant; comparatively few of the tassel buds are destroyed. The injury to tassel stems, frequently causing them to break over, is of more concern, but even this more wholesale destruction of tassel buds is not, even in the worst cases, a serious matter, since there has not been noted any reduction in pollination of the ears. The extent to which tassel stems are thus injured is shown in table 21. These figures, however, do not represent the most severe infestations. There is a greater tendency for indirect reduction in yield when the injury is lower in the stalk, especially when it is below the ears, because it would there effect to a greater extent the vascular system of the whole plant. Infestation very low in the plant has a further importance. It is this lowest part of the plant that is so frequently left in the field as stubble and that carries many borers over the winter. (See page 12 and table 2.)

The early feeding on the tassel buds leaves no visible injury except by a minute examination of the tassels. The injury to the tassel stems, however, usually results in their breaking over. These broken-over tassels soon lose their green color and become the most conspicuous indications of the presence of borers (fig. 11). Such signs are seldom missing even in the lightly infested fields, but should not be entirely depended upon in scouting for infestation, since most plants are attacked lower down. There is little visible injury to the plants until the young larvae start to tunnel into the stems. At this time much of the excrement or frass is cast out of the entrance holes and is commonly seen clinging to the plant by the strands of silk, which hold it in loose lumps, or lodged in the leaf corners (fig. 12). This frass is often dislodged by wind and rain, making it more difficult to detect lightly infested plants. As the season advances, the infestation becomes more and more evident by an increased number of injured points along the stalk, a greater amount of frass, and an increasing number of broken-over stalks. By late fall a badly infested field shows a great many stalks broken-over and some ears on the ground.

It is necessary to dissect the stems to see the real injury. Between the leaf-sheath and the stalk of an infested internode, there is an accumulation of frass more or less mixed with the jellied juice of the plant, and the silk of the insect. Within the stems are the tunnels of the borers, together with much frass that was not extruded from the holes. Sometimes the whole interior of the stems is reduced to a sawdusty mass, no pith tissue being left intact (fig. 13). This is unusual, however, for in most cases the tissue destroyed is only a fraction of that present (fig. 3). An excellent, detailed description of the appearance of injury in the stems follows[16]:

"After the larva has entered the stalk it tunnels upward or downward. The character of the tunnel is subject to great variation, but typically the larva follows a nearly straight course through the pith and generally lengthwise of the plant. In some instances the tunnel is more or less winding and occasionally small cells are excavated along its course. Sometimes the larva also excavates a large horizontal chamber either just above or just below the entrance hole and starts its tunnel from this chamber. Stalks bearing this type of tunnel are greatly weakened and soon break over. All parts of the stalk may be tunneled down to and including the base or stubble. There is a tendency for the larvae to work in the internodes of the stalk, but many of the nodes are also perforated, especially where several larvae are present in the same stalk."

[16] This is quoted from Caffrey, D. J. 1927. A Progress Report on the Investigations of the European Corn Borer. 155 p., illus.

EARS

In most cases the ears are not as frequently attacked as are the stalks. The bulk of the ear injury occurs late in the season on late planted sweet corn, and is inflicted by the second generation borers. Sometimes this ear infestation actually exceeds that in the stalks. For example, note the June 20 planting of Golden Bantam sweet corn, recorded in table 21. For the most part, first generation infestation is largely confined to the stalk, but in very early sweet corn the ears sometimes become badly infested. Since the second generation infestation does not come early enough to greatly reduce the yield indirectly by stem injury, the tendency is for the late corn to show the greatest amount of direct injury and the early corn the greatest amount of indirect injury.

The infestation of the ears consists of varying amounts and combinations of injury to the sheaths, silk, cob, shank[17], and kernels. The number of larvae found in the different parts of the ear are shown in table ~~20~~ 23. It will be noted that in the sweet corn, which was examined in the milk stage, the greatest number are in the silk, with a considerable number in the sheaths and grain, but that in the field corns, examined when the grain was hard, there was practically none in the silk and comparatively few in the sheaths, most of them being in the cobs, shanks, and grain. This is because the silk and sheaths became dried up late in the season. For the most part, actual kernel injury is small, especially in sweet corn. Occasionally it reaches as high as 10 per cent or even more in field corn. In sweet corn, however, it is not necessary that the damage be done to the kernels to reduce ~~their~~ the value; the presence of injury in any part of an ear is sufficient to reduce its value, or even cause it to be rejected. The number of ears injured anywhere and the larval content is shown in tables ~~20~~, 21 ~~and~~ 22, and 23.

[17] See footnote 15, page 43.

The husk injury is confined to a little feeding on the inner sheaths, and to small holes through to the outside of the husks. Frass is often extruded from these holes (fig. 12). Although silk is freely fed upon and is sometimes completely sheared off, there has been no noticeable interference with fertilization of the kernels. Infested ears commonly show frass mixed with the silk and extruding from their tips (fig. 14). Injury to the shank consists in tunnels across it, or throughout its length. The longitudinal tunnel is often continued through the center of the cob. The cob may also have cross tunnels, and, in the case of ears which have a tip of cob extending beyond the kernels, the tender end is freely attacked and sometimes completely devoured (fig. 14).

The kernel injury may vary from the destruction of a single kernel to that of the entire ear in extreme cases. The injury most frequently occurs near and extends down from the ear-tips (fig. 14), but feeding areas are also found farther down on the ear where larvae have entered through the husks. The attacks through the husks may be found anywhere throughout the length of the ear. These feeding areas, which are made while the grain is still in the milk or early dough stages, may be irregular or linear in outline (fig. 14), and ordinarily do not involve more than a dozen kernels. There are two other types of kernel injury which occur when the grain becomes harder. One of these is made by a larva tunneling through a row of grain at the base of the kernels, eating its way through the germs of the seeds. Sometimes several inches of a row will thus be tunneled. Outwardly, the ear appears practically unharmed, but a slight lateral pressure upon the injured kernels causes the shells that remain of them to drop out. The other type is caused by a larva passing through the triangular space formed by the upper rounded corners of the kernels of two adjacent longitudinal rows with the surrounding sheaths. As a larva progresses through this passage, it rasps off the corners of the kernels, usually little

more than destroying the epidermis, but frequently doing it throughout the length of the ear. Such injury is negligible in itself, but it makes an unsightly ear, and allows disease to enter, ~~in~~. Although the work of the European corn borer in the ears is quite distinctive, there is considerable excuse for confusing it with that of the corn earworm (*Heliothis obsoleta* Fab.). The corn earworm, however, makes a deeper and broader excavation, almost invariably feeds on the tip, or from the tip downward, and leaves frass consisting of larger pellets.

That there is an indirect loss in yield of ears caused by injury to the stems is appreciated by all who are in close touch with this problem. But attempts to measure this loss have so far been rather unsuccessful; the results have been contradictory and questionable. As a matter of fact, there is probably a great variation in the amount of loss, resulting from various causes, especially the location and time of the attack. Other things that have made a measurement of this injury difficult are the presence of large suckers, that are indistinguishable from the main stalks, migration of larvae, and uneven stands of corn. The injury apparently affects a delay in the growth of the ears and a reduction in their number and size. There has not been noticed any appreciable loss in quality. In table 25 an experiment is reported which gave results that ~~which~~ might be expected. It shows a decided loss in number, weight, length, volume, and ~~number of~~ kernels of the ears of both the medium and heavily infested plants over the lightly or non-infested plants. Most of the experiments show this tendency to indirect injury in infested plants, but a few have given opposite results. It will be necessary to carry this work on for some time yet before any definite conclusion as to the extent of loss can be made.

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SUMMARY

Most of the detailed experiments concerning the food plants of the European corn borer have been conducted on corn, because it is the most important host of this insect. The greater part of this work was carried on under natural conditions, but it was necessary to resort to artificial infestation in some cases. This was accomplished either by inducing the moths to lay eggs, or by placing newly hatched larvae, on the plants. The principal data collected were the proportion of plants and ears infested, the amount of grain destroyed, and the larval content of infested plants and ears. Samples of 10 to 100 ears or plants were examined in each case, and an attempt was made to eliminate error by having all check conditions uniform, by replication of plots, and by providing as much isolation as possible.

A knowledge of this insect's depredations on its host plant, and the suitability of the plant for its guest involves a study of the seasonal cycle of the insect, its life stages, and its habits - all correlated with the characteristics, development, growth, and condition of the plant. Information on these subjects is important in all control measures. The relationship of the seasonal history of the borer and the development of the plant is intricate; it is variable and constantly changing. Both the insect and the plant, therefore, must be watched throughout the year. The most disastrous combinations of insect and plant development are: first, plants large enough to be attractive to the moths of the overwintering generation as oviposition sites, since the resulting larvae will enter the stalks and cause injury that will reduce the number and size of the ears, and, second, plants that are developing ears at the time when newly hatched larvae are crawling over them.

The corn plant makes an excellent, although not perfect, host for this insect. It is usually in a suitable stage to receive oviposition. It furnishes the best of entrance points for the invading larvae of both generations. It is large enough to furnish protection and food for a large number of borers. Most parts of the plant are used as food; the bulk of nourishment is furnished by the inner side of the leaf-sheaths, silk, and kernels. This plant also furnishes excellent protection to hibernating larvae. It is not, however, always suitable for the borer's needs. Its rapid development sometimes forces the borers, before they are grown, to move to more succulent parts with a loss of numbers in migration; it may injure borers mechanically; it is sometimes too dry to be attractive to the moths as an oviposition site, or suitable as food for the larvae.

The seasonal cycle is complicated by the presence of both single and two generation individuals, but for the most part it is sufficient to consider only two broods. There is a tendency for the earlier emerging moths to give rise to two generations, and the later emerging moths to one generation. The complication of generations is involved with the amount of injury inflicted on corn planted on different dates. The second generation is the most numerous and does the greatest amount of direct injury. The egg and larval stages show the most important differences in the relationship of the two broods to the corn plant, but it is interesting to note the status of the pupae and adults. Pupation of the first generation takes place in growing plants in the summer; pupation of the overwintering borers takes place in debris in the spring. The plants seem to be in a more attractive stage of development at the time the second brood of moths (first generation) are active than when the first brood of moths (from overwintering borers) are active.

The first of the two oviposition periods takes place while the plants are relatively small. The eggs are laid on the lower leaves, near the stalks, of the larger plants. The place of oviposition has little to do with where the plants may first be invaded. The little larvae crawl freely all over the plant and eventually descend into the vortical part and begin their feeding on the leaf tissue just out of sight - not deep in~~to~~ the plant.

Second generation eggs are laid at a time when most of the plants have reached the stage of inflorescence. Like the first brood, they are laid on the under-side of the leaves, usually near the stalk, but they are found higher in the plant, and are frequently also laid on the ear-foliage. The newly hatched larvae of this generation, like those of the first, show a decided tendency to wander over the plant before starting to feed. In this case, however, the points of invasion are the leaf-sheaths and the ends of the ears; a few attack leaf-ribs. The larvae start to tunnel into stems during the third and fourth instars, but they work their way gradually into the ears; there is no particular instar when they start tunneling into the ear tissues. After entering the stem the larvae at first work upward, and later in all directions. Rudimentary ears are treated as true ears when considering larval invasion. The central parts of the plant are most freely invaded; this seems to be directly correlated with the location of oviposition. The occurrence of eggs on the ear-foliage does not greatly increase ear infestation.

The corn borer, in common with most insects, has a tremendous potential increase in numbers. Survival figures are based on the number of eggs laid and the number of larvae found at any given time; the ratio is termed "larval establishment." Any deductions from the figures at hand are questionable. There appears to be a slightly higher rate in sweet corn and in the second generation. Establishment from artificially infested corn is low. This is probably the result of emigration. Eggs may fail to hatch; they may be destroyed by weather conditions; they may be attacked by predaceous insects or parasitized. The larvae are subject to all these destroying agencies to even a greater extent than are the eggs. Other factors which affect establishment are concentrations of larvae, parts of the plant entered, and season of hatching.

Although most of the corn borer investigations are involved with migration, little is known on this subject more than the obvious disper-s~~ion~~al of newly hatched larvae, and the general migration of large larvae from overpopulated or disturbed plants. Although the newly hatched larvae crawl freely over the plants of a hill, there is a tendency for them to remain on the plant where the eggs were laid. There is an even stronger tendency for them to remain on the hill where the eggs were laid rather than become established on other hills. Larvae are known to migrate two or three hills away from their original location, and may attain greater distances. There is a movement of larvae throughout the season, but little is known about its volume or nature. This continual movement is tied up with movements from one part of the plant to another.

The corn plant is attacked freely in all parts except the roots, but the real injury is restricted to stems and ears. Any study of infestation in the different parts must take into consideration migration. The larval content and the extent of injury varies with the stage of the insect, the age of the corn, and the time of season. There is usually a direct correlation of number of borers with injury, but it does not always hold. Under certain conditions the number of borers may be out of proportion to the injury done.

The injury to the leaves consists of feeding areas and holes in the blades, tunneling into the mid-ribs, and destruction of tissue on the inner side of the sheaths. Early leaf feeding is not as prevalent as later stalk feeding. The injury to the leaf sheaths is about three times as frequent as that to the leaf-ribs. The early leaf-blade feeding areas are characteristic. Most of them do not extend clear through the leaf, but leave the epidermis on one side intact. The rib injury causes the leaves to break over. The injury to the sheaths is seen only on dissection.

The stems are the parts most frequently attacked. The larvae tunnel into the stems during the third and fourth instars and make the greatest inroads on the plant tissue from this time on. Suckers are not so frequently infested as the main stalks. Infestation in the stalk and suckers interferes with the vascular system. Some work has been done to show the extent of infestation in the different parts of the stalk. The early feeding in the tassel buds causes insignificant injury; the breaking-over of tassel stems is more important, but also negligible. Infestation lower down in the stalk tends toward an increased amount of indirect injury. Injury to the tassel buds does not show, when the plants are grown, but tassel stem injury results in many broken-over tassels, one of the most obvious signs of infestation in a field. When the larvae start to tunnel into the stem, frass is thrown out which lodges in the leaf axes or clings to the entrance holes, held by strands of silk. Inside the stems the pith is tunneled to a greater or less extent, and both stem and leaf sheaths contain quantities of frass.

The ears are usually less frequently attacked than are the stalks, but sometimes in late planted sweet corn the reverse is true. For the most part, the first generation affects the ears indirectly by attacking the stems, and second generation attacks the ears directly. All parts of the ears are attacked. When the ears are young most of the larvae are in the silk and sheaths, but as they become more mature most of the larvae are in the cob, shank, and grain. Actual kernel injury is usually small, but if sweet corn ears are infested anywhere, it affects their value. Husk injury consists of holes in the sheaths through which frass exudes. Although silk injury is common and sometimes all the silk is sheared off, there is no apparent effect on fertilization of the kernels. Shank and cob injury consist in tunnels through them. The extent of kernel injury varies a great deal and usually occurs near the tips of the ears. Most of the kernel feeding is done while they are still soft. In appearance ear injury is distinctive, but there is some excuse for confusing it with that done by the corn earworm (<u>Heliothis</u> <u>obsoleta</u> Fab.). Indirect injury is known to occur, but it is difficult to measure. It varies a great deal with the season, and with the parts of the plant attacked. Definite conclusions as to the extent of this loss can not yet be made.

BIBLIOGRAPHY

These publications and text books have been studied and used as references in-so-far as they apply to the subject of this thesis.

Ainslie, G. G. 1910. The larger corn stalk-borer (Diatraea saccharalis Fab.). Farmers' Bul. 1025, 12 pp., illus.

Ainslie, G. G. and Cartwright, W. B. 1921. Biology of the smartweed borer, Pyrausta ainsliei Heinrich. Jour. Agr. Research (U. S.) 20: 837-844, illus.

Ainslie, G. G. and Cartwright, W. B. 1922. Biology of the lotus borer (Pyrausta penitalis Grote). U. S. Dept. Agr. Bul. 1076, 14 pp., illus.

Bailey, L. H. 1924. Manual of cultivated plants. A flora for the identification of the most common or significant species of plants grown in the Continental United States and Canada for food, ornament, utility, and general interest, both in the open and under glass. The Macmillan Company.

Barber, G. W. 1924. Migration - an important habit of the European corn borer. Jour. Econ. Ent. 17: 582-589, illus.

Barber, G. W. 1924. The importance of winter mortality in the natural control of the European corn borer in New England. Psyche 31: 279-282, illus.

Barber, G. W. 1925. Remarks on the number of generations of the European corn borer in America. Jour. Econ. Ent. 18: 496-502.

Barber, G. W. 1925. A study of the cause of the decrease in the infestation of the European corn borer (Pyrausta nubilalis Hubn.) in the New England area during 1923. Ecology 6: 39-47.

Barber, G. W. 1925. Observations on the response of adults of the European corn borer to light in egg laying. Ann. Ent. Soc. Amer. 18: 419-431, illus.

Barber, G. W. 1926. A two-year study of the development of the European corn borer in the New England area. Jour. Agr. Research (U. S.) 32: 1053-1068.

Barber, G. W. 1926. Some factors responsible for the decrease of the European corn borer, in New England 1923 and 1924. Ecology 7: 143-162.

Barnes, C. R. See Coulter.

Bradley, W. G. See Jones, T. H.

Brues, C. T. 1920. The selection of food plants by insects with special reference to lepidopterous larvae. Amer. Nat. 54: 313-332.

Caffrey, D. J. 1928. Recent developments in entomological research on the corn borer. Jour. Amer. Soc. Agronomy, v. 20, pp. 997-1010.

Caffrey, D. J. See Worthley.

Caffrey, D. J. See Vinal.

Caffrey, D. J. and Huber, L. L. 1928. The fundamental phases of European corn borer research. Jour. Econ. Ent. 21: 104-107.

Caffrey, D. J. and Worthley, L. H. 1927. A progress report on the investigations of the European corn borer. U. S. Dept. Agr. Bul. 1476: 1-146, illus.

Cartwright, W. B. See Ainslie.

Coulter, J. M., Barnes, C. R., Cowles, H. C. 1910. A textbook of botany for colleges and universities. American Book Co.

Cowles, H. C. See Coulter.

Eames, A. J. and MacDaniels, L. H. 1925. An introduction to plant anatomy. McGraw-Hill Book Co. Inc.

Ellis, W. O. 1925. Some lepidopterous larvae resembling the European corn borer. Jour. Agr. Research (U. S.) 30: 777-792, illus.

Fernald, H. T. 1926. Applied entomology. An introductory text-book of insects in their relations to man. Second edition 395 p., illus. McGraw-Hill Book Co. Inc.

Folsom, J. W. 1922. Entomology with special reference to its ecological aspects. Third revised edition. P. Blakiston's Son & Co.

Forbes, W. T. M. 1923. The lepidoptera of N. Y. and neighboring states. Cornell Univ. Agr. Exp. Sta. Memoir 68.

Ganong, W. F. 1916. A textbook of botany for colleges. The Macmillan Co.

Haley, W. E. See Halloway.

Halloway, T. E. 1921. The European corn borer and sugar cane moth borer: a comparison. Jour. Econ. Ent. v. 14. #6, p. 481.

Halloway, T. E. and Haley, W. E. 1927. Moth borer damage to different varieties of sugar cane. Jour. Econ. Ent. v. 20. #5, p. 703.

Hayes, W. P. 1922. Observations on insects attacking sorghums. Jour. Econ. Ent. v. 15, #5, p. 349.

Holmes, S. J. 1911. The evolution of animal intelligence. Henry Holt & Co.

Huber, L. L. See Caffrey.

Huber, L. L.; Neiswander, C. R.; and Salter, R. M. 1928. The European corn borer and its environment. Ohio Agr. Exp. Sta. Bul. 429.

Jones, T. H. and Bradley, W. G. 1924. Certain wild grasses in relation to injury to corn by the borer, Diatraea saccharalis, in Louisiana. Jour. Econ. Ent. v. 17, #3, p. 393.

MacDaniels, L. H. See Eames.

Montgomery, E. G. 1920. The corn crops A discussion of maize, kafirs, and sorghums as grown in the United States and Canada. Revised edition. The Macmillan Co.

Neiswander, C. R. See Huber.

Parker, H. L. See Thompson.

Patch, L. H. 1929. Some factors determining corn borer damage. Jour. Econ. Ent. v. 22, #1, Feb. 1929.

Plank, H. K. 1928. The lesser corn stalk-borer. Jour. Econ. Ent. v. 21, #2, p. 413.

Robbins, W. W. 1917. The botany of crop plants A text and reference book. P. Blakiston's Son & Co.

Stevens, W. C. 1924. Plant anatomy from the standpoint of the development and functions of the tissues and handbook of microtechnic. Fourth edition, revised. P. Blakiston's Son & Co.

Thatcher, R. W. 1921. The chemistry of plant life. 268 p. The McGraw-Hill Book Co. Inc.

Thompson, W. R. and Parker, H. L. 1928. Host selection in Pyrausta nubilalis Hubn. Bul. Ent. Research, v. 18, pp. 359-364, May 1928.

Thompson, W. R. and Parker, H. L. 1928. The European corn borer and its controlling factors in Europe. U.S.D.A. Tech. Bul. 59: 62 pp., illus.

Vinal, S. C. and Caffrey, D. J. 1919. The European corn borer and its control. Mass. Dept. Ent. Bul. 189.

Wade, J. S. 1928. A bibliography of the European corn borer (Pyrausta nubilalis Hubn.) U. S. D. A. Misc. Cir. 46.

Worthley, L. H. See Caffrey.

Worthley, L. H. and Caffrey, D. J. 1927. Scouting, quarantine and control for the European corn borer, 1917-1926. U. S. D. A. Tech. Bul. 53.

Table / Parts of the corn plant serving best as food

Part of plant	Number of larvae started	Pupation obtained	
		#	%
Silk	25	22	88
Kernels	25	18	72
Inside foliage	75	29	39
Tassel buds	75	7	9
Stem pith	125	11	9

Newly-hatched larvae were segregated to individual two-inch shell vials, and food was changed every few days. Only tender growing tissues were used as food. The foliage used was the pale green leaves that had not been exposed to the sun. Two series were tried on the mature green leaves, but larvae failed to develop on both; this may have been because of the difficulty of keeping the green leaves from drying out.

Table 2 Record of overwintering borers found in debris of corn fields

Field #	Area of field (acres)	Material found in 5 sq. rods of each field: Linear ft. of debris	# live borers	# dead borers	Estimated borer population: In the plants in the fall	In the debris in the spring
			1926			
1	2.0	707	0	0	10,167	0
2	1.5	184	18	15	793,576	864
3	1.4	736	7	4	4,539	392
			1927			
1	1.0	125	7	6	33,300	224
2	1.0	93	16	3	3,470	512
3	3.0	89	3	1	4,170	288
4	2.4	144	3	0	1,050	230
5	1.5	363	2	0	6,720	96
6	2.8	162	2	1	4,350	179
			1928			
1	0.8	93	7	2	1,610	179
2	0.5	108	41	4	4,950	656
3	0.6	107	3	1	5,190	58
4	0.8	66	3	1	3,346	72
5	2.5	65	2	2	15,892	160
6	1.0	67	6	1	13,250	192
7	1.0	73	1	0	2,412	32
8	0.3	26	0	0	4,730	0
9	0.8	87	3	1	44,254	102
10	0.8	121	10	1	9,657	256
11	0.8	167	14	3	39,933	358
12	1.3	208	7	1	5,928	291

(Table 2 continued)

Field #	Area of field	Material found in 5 sq. rods of each field: Linear ft. of debris	# live borers	# dead borers	Estimated borer population: In the plants in the fall	In the debris in the spring
			(1928 continued)			
13	0.7	65	3	2	3,298	67
			1929			
1	0.9	13	0	0	4,680	0
2	1.5	93	23	2	14,508	1,104
3	2.3	34	0	0	8,538	0
4	0.9	19	2	0	2,429	58
5	1.0	51	0	0	492	0
6	0.3	14	0	0	0	0
7	2.0	41	1	0	1,688	64
8	2.8	24	1	0	124,416	90
9	1.4	12	0	0	405	0
10	1.6	27	2	0	8,316	102
11	1.3	101	6	2	7,254	250
12	1.5	84	5	1	4,788	240
13	1.0	81	4	0	8,520	128
14	1.2	56	0	0	2,036	0
15	1.1	91	9	1	11,035	317
16	1.1	399	1	1	27,900	35
17	1.7	22	3	0	6,446	163
18	3.8	26	8	3	34,496	973
19	0.8	28	2	0	7,409	51
20	1.0	259	50	5	21,466	1,600
21	1.8	103	30	7	32,917	1,728
22	1.2	53	9	1	43,517	346

(Table 2 continued)

Field #	Area of field	Material found in 5 sq. rods of each field: Linear ft. of debris	# live borers	# dead borers	Estimated borer population: In the plants in the fall	In the debris in the spring
			(1929 continued)			
23	0.5	103	25	5	39,548	400
24	1.4	66	0	0	4,312	0
25	1.3	109	4	0	3,780	166

Practically all debris consisted of parts of corn plants, mostly stubble and pieces of stalks which were left after the fall clean-up of plants. In most cases the stalks had been removed before plowing. Most of the fields were plowed in the fall, and some in the spring, also, before the examinations were made. No live borers were found in the fragments of debris completely covered with earth.

Table 3 Correlation of time of oviposition and the number of generations

Group	Period of oviposition	Total egg masses	Total eggs	Number larvae	Number pupae and adults	Proportion of single generation
						%
Early emerged moths	June 11 to 30	230	6305	96 [1]	86 [1]	52.7
Late " "	July 14 to 26	374	8590	1133	103	91.7

[1] Dissections were made in September after pupation had ceased.

Waltham experiment field, 1929.

Table 4 Distribution of first generation egg masses

	Leaf number from ground up: 1	2	3	4	5	6	7	8	9	10	Total
Golden Bantam sweet corn, 1st planting											
Proximal-third	4	7	6	1	1						19
Mid-third	1	1	2								4
Distal-third					1						1
Total	5	8	8	1	2						24
Early Canada flint corn, 1st planting											
Proximal-third	7	12	9	6	2						36
Mid-third	2	4	1	2	1						10
Distal-third	3	1	2	1	1						8
Total	12	17	12	9	4						54
Pride of the North dent corn, 1st planting											
Proximal-third	2	9	4	3				1		1	20
Mid-third	2	2	1			1					6
Distal-third		1			2		1				4
Total	4	12	5	3	2	1	1	1		1	30
Total of the three types											
Proximal-third	13	28	19	10	3			1		1	75
Mid-third	5	7	4	2	1	1					20
Distal-third	3	2	2	1	4		1				13
Total	21	37	25	13	8	1	1	1		1	108

Of the above egg masses, 12 of the 75 laid on the proximal-third of the leaf were laid at the base of the leaf. Only 3 of the 108 masses were laid on the upper side of the leaf.

Waltham experiment field, 1929.

Table 5 Length of life of newly-hatched larvae without food

Group number[1]	Number of larvae alive				
	1st day	2nd day	3rd day	4th day	5th day
1	12	12	12	0	0
2	8	8	1	0	0
3	20	19	16	0	0
4	8	8	2	0	0
5	12	12	10	0	0
6	15	14	3	0	0
7	10	5	0	0	0
8	25	25	23	2	0
Total	110	103	67	2	0

Per cent living second day (approximately 24 hours)	94.0
" " " third " " 48 "	61.0
" " " fourth " " 72 "	1.8
" " " fifth " " 96 "	0.0

[1] Each group represents the larvae from a single egg mass minus those that were injured or lost during the experiment (there were five of these). It will be noticed that the greatest amount of mortality occurs between 48 and 72 hours. More careful experiments would probably show a mean length of life for unfed larvae to occur at some point during this time. All newly hatched larvae were isolated to avoid cannibalism.

Table 6 First generation larval invasion of the plants [1]

Experiment A. Started July 14, 1928. Approximately 100 larvae set on each of 3 plants in each of 10 groups. Plants 15 inches high and starting to develop tassels.

	Group numbers									
	1	2	3	4	5	6	7	8	9	10
Number of larvae set	303	307	302	300	318	316	302	305	313	300
Time to dissection in days	1	2	3	4	5	8	12	17	23	30
Borers recovered in tassel	14[2]	57	62	29	65	39	42	17	--	--
Borers recovered in foliage and stems	99	51	15	37	34	16	14[3]	49[4]	51[5]	29[5]
Borers recovered (total)	113	108	77	66	99	56	56	66	51	29
Modal instar	1	1	1	2	2	2	3	3	4	5
Larval establishment in per cent	37	35	25	22	31	18	19	22	16	10

Experiment B. Started July 15, 1928. Approximately 100 larvae set on each of 20 hills (each group represents 2 hills of 4 plants each, or 8 plants). Plants 6 to 8 inches high and did not develop tassels till end of experiment.

	1	2	3	4	5	6	7	8	9	10
Number of larvae set	203	203	192	205	204	206	202	202	199	200
Time to dissection in days	1	2	3	4	5	8	15	17	23	30
Borers recovered [6]	34	16	26	5	15	11	13	10	14	10
Modal instar	1	1	1	2	2	2	3	3	4	5
Larval establishment in per cent	17	8	14	2	7	5	6	5	7	5

Experiment C. Started July 3, 1929. One hundred larvae set on each of 20 hills (each group represents 2 hills of 2 plants each or 4 plants).

	1	2	3	4	5	6	7	8	9	10
Time to dissection in days	1	2	4	6	9	12	16	20	25	30
Height of plant in inches	5.5	6	7	9	14	20	22	27	30	34
Borers recovered on green leaf	15	5	6	6	1	--	1	1	--	1
" " " inner leaves	--	4	9	5	1	--	6	2	1	2
" " in leaf-rib	--	--	--	--	--	1	4	1	2	--
" " " leaf-sheath	--	--	2	4	3	3	1	2	--	1
" " " tassel-buds [6]	--	--	--	--	--	--	--	--	2	--
" " " stems	--	--	--	--	--	--	--	--	1	2
" " (total)	15	9	17	15	5	4	12	6	6	6
Modal instar	1	1	1	1	2	2	3	3	4	5
Larval establishment in per cent	7.5	4.5	8.5	7.5	2.5	2	6	3	3	3

(Table 6 continued)

[1] Golden Bantam sweet corn was used in the three experiments. All larvae were newly-hatched when placed on the plants. In experiments A and B the plants were infested by inverting two-inch vials, containing the larvae, into the center of the plant; in experiment C medicine capsules containing the larvae were opened and cemented to the underside of the leaves to simulate the condition of natural infestation. This work was all done at the Waltham experiment field.

[2] There was only one tassel developed in this group of three plants, hence the lower number of larvae attacking the tassel.

[3] Seven of these were tunneled into the plant.

[4] Most of these were within the leaf sheaths or tunneled into the stems.

[5] Mostly tunneled into the stems.

[6] Most of the larvae became established in some part of the leaves before the tassels became sufficiently large to attract them.

Table 7 Distribution of second generation egg masses

Part of leaf	Leaves of stems (stalks) Lower	Middle	Upper	Total	Ear foliage	Total plant
	Group A. Golden Bantam sweet corn					
Proximal-third	9	6	1	16		
Mid-third	5	4	1	10		
Distal-third	0	1	2	3		
Total	14	11	4	29	17	46
	Group B. Golden Bantam sweet corn					
Proximal-third	11	9	8	28		
Mid-third	13	16	6	35		
Distal-third	4	5	3	12		
Total	28	30	17	75	28	103
	Group C. Pride of the North dent corn					
Proximal-third	11	28	29	68		
Mid-third	6	11	16	33		
Distal-third	7	10	6	23		
Total	24	49	51	124	7	131
	Total of the three groups					
Proximal-third	31	43	38	112		
Mid-third	24	31	23	78		
Distal-third	11	16	11	38		
Total	66	90	72	228	52	280

(Table 7 continued)

Of the 112 egg masses laid on the proximal-third of the leaf, 44 were laid at the base of the leaf. Only 12 of the 280 masses were laid on the upper side of the leaves; one was laid on a leaf sheath; and one mass, not included in the 280, was laid on the stalk.

The groups represent typical plantings in each case. A, the first planting of Golden Bantam sweet corn, made April 26, 1928, B, the fourth planting of Golden Bantam sweet corn, made June 6, 1928, and C, the first planting of Pride of the North dent corn, made April 26, 1928. This work was done at the experiment field, Waltham, Mass.

Table 8 Second generation larval invasion of the corn plant[1]

Path of larvae	Groups of plants[2]: 1 larvae	1 abandoned tunnels	2 larvae	2 abandoned tunnels	3 larvae	3 abandoned tunnels	4 larvae	4 abandoned tunnels	Total larvae	Total abandoned tunnels
In leaves										
In rib from upper side[3]	12		2	4	1	0	0	0	15	4
" " " lower "	1		1	2	0	0	0	0	2	2
" sheath from upper side	33		3	0	6	0	3	0	45	0
" " " lower "	2		0	0	0	0	0	0	2	0
In stems (stalk and suckers)										
Entered at internode via sheath	202		23	10	37	2	34	4	296	16
" " node " "	149	No record	25	1	40	0	30	2	244	3
" " internode through sheath	80		14	2	8	0	1	0	103	2
" " node at base of sheath	143		42	0	26	2	17	1	228	3
" " " " top " "	68		20	2	5	0	26	0	119	2
" " tassel stem	29		6	2	8	0	7	0	50	2
Total in plant (exclusive of ears)	719		136	23	131	4	118	7	1104	34
In ear[4]										
Entered through silk	213		62	1	9	3	21	0	305	4
" " ear-sheaths	88		64	1	7	0	7	0	166	1
" " shank	26		3	0	0	0	1	0	30	0
" shank between ear-sheaths	4		1	0	1	0	3	0	9	0
" " through " "	51	No record	9	0	3	0	0	0	63	0
" " from inside leaf-sheath	84		62	1	21	0	21	0	188	1
" " " stalk	0		1	0	0	0	0	0	1	0
Total in ears	466		202	3	41	3	53	0	762	6
Total in plant (including ears)	1185		338	26	172	7	171	7	1866	40

Path of larvae	Groups of plants[2]									
	1		2		3		4		Total	
	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels
Leaves										
In rib from upper side[3]	12	No record	2	4	1	0	0	0	15	4
" " lower "	1		1	2	0	0	0	0	2	2
" sheath from upper side	33		3	0	6	0	3	0	45	0
" " lower "	2		0	0	0	0	0	0	2	0
Stems (stalk and suckers)										
Entered at internode via sheath	202		23	10	37	2	34	4	296	16
" " node " "	149		25	1	40	0	30	2	244	3
" " internode through sheath	80		14	2	8	0	1	0	103	2
" " node at base of sheath	143		42	0	26	2	17	1	228	3
" " " " top " "	68		20	2	5	0	26	0	119	2
" " tassel stem	29		6	2	8	0	7	0	50	2
Total in plant (exclusive of ears)	719		136	23	131	4	118	7	1104	34
Ear[4]										
Entered through silk	213	No record	62	1	9	3	21	0	305	4
" " ear-sheaths	88		64	1	7	0	7	0	166	1
" " shank	26		3	0	0	0	1	0	30	0
" shank between ear-sheaths	4		1	0	1	0	3	0	9	0
" " through "	51		9	0	3	0	0	0	63	0
" " from inside leaf-sheath	84		62	1	21	0	21	0	188	1
" " " stalk	0		1	0	0	0	0	0	1	0
Total in ears	466		202	3	41	3	53	0	762	6
Total in plant (including ears)	1185		338	26	172	7	171	7	1866	40

(Table 8 continued)

The same larvae and abandoned tunnels found in leaves and stalks, arranged according to internodes where they were found.

Nodes from top down [5]	Groups of plants 1		2		3		4		Total	
	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels	larvae	abandoned tunnels
Tassel stem	29	Not recorded	6	2	8	0	7	0	50	2
1 internode	95		4	12	10	2	8	3	117	17
2 "	55		13	1	13	0	10	0	91	1
3 "	84		15	4	18	0	16	1	133	5
4 "	120		14	3	20	0	10	3	164	6
5 "	124		20	1	22	0	15	0	181	1
6 "	85		19	0	14	2	13	0	131	2
7 "	68		22	0	14	0	21	0	125	0
8 "	42		14	0	12	0	11	0	79	0
9 "	16		9	0	0	0	7	0	32	0
10 "	1		0	0	0	0	0	0	1	0
Total	719		136	23	131	4	118	7	1104	34

1 This work was done October 6 to 11, 1927, before a large part of the larvae had reached their final hibernating quarters, but after most of them had entered the stems or ears.

(Table 8 continued)

2 Group 1 consisted of 337 infested plants from a plot of Early Crosby sweet corn, planted May 23; total number of ears 272. Group 2 consisted of 37 infested plants from a plot of Early Crosby sweet corn, planted June 20; total number of ears 32. Group 3 consisted of 50 infested plants of Stowell's Evergreen sweet corn, planted May 23; total ears 25. Group 4 consisted of 50 infested plants of Stowell's Evergreen sweet corn, planted June 6; total ears 32.

3 Unfortunately abandoned tunnels were not recorded in group 1. There was doubtless a large number of these in the leaf-ribs.

4 In groups 1 and 2 the larger rudimentary ears, having considerable exposed sheath and silk, were included in the ear records.

5 The plants ran from 7 to 10 internodes, thus making the basal internode vary between these numbers. This, as well as the lesser infestation low in the plant, would contribute to the lowered figures, especially in internodes 9 and 10.

6 In only 49 cases was there more than 1 larva at an internode.

Table 9 Comparative invasion of true ears versus rudimentary ears.[1]

Path of larvae	Group 1		Group 2		Group 3	
	True ears	Rudimentary ears	True ears	Rudimentary ears	True ears	Rudimentary ears
Entered ear through silk	44	39	17	12	61	51
" " " ear-sheaths	46	25	9	10	55	35
" " " shank	3	0	1	1	4	1
" shank " ear-sheaths	20	22	2	6	22	28
" " via leaf-sheath	92	31	31	18	123	49
Total larvae	205	117	60	47	265	164

1 This work was done October 6 to 11, 1927, at the Medford experiment field. Group 1 consisted of 91 true ears and 59 rudimentary ears from 100 infested plants of Early Crosby sweet corn, planted April 26. Group 2 consisted of 33 true ears and 29 rudimentary ears from 50 infested plants of Stowell's Evergreen sweet corn, planted May 9.

Table 10 Place of second generation oviposition as effecting subsequent larval invasion [1]

	Oviposition on stalk foliage: Upper	Lower	Total	Ovi-position on ear foliage	Check no ovi-position recorded
Experiment A. Natural oviposition					
Number of plants			17	7	22
" " eggs			394	227	0
" " larvae recovered					
In stalks			30	16	45
In ears			41	21	48
Total			71	37	93
Average per plant			4.2	5.3	4.2
Per cent of recovered larvae in ears			58	57	52
" " " larval establishment			18	16	--
Experiment B. Artificial oviposition [2]					
Number of hills			2	2	2
" " eggs			730	783	0
" " larvae recovered					
In stalks			19	46	38
In ears			52	87	36
Total			71	133	74
Per cent of recovered larvae in ears			73	65	49
" " " larval establishment			9.7	17.0	--

(Table 10 continued)

	Oviposition on stalk foliage: Upper	Oviposition on stalk foliage: Lower	Oviposition on stalk foliage: Total	Oviposition on ear foliage	Check no oviposition recorded
Experiment C. Both natural and artificial oviposition[2]					
Number of plants			15	20	29
" " eggs			1140	1735	--
" " larvae recovered					
In stalks			59	91	84
In ears			101	211	117
Total			160	302	201
Average per plant			10.7	15.1	6.9
Per cent of recovered larvae in ears			63	70	58
" " " larval establishment			14	17	--
Experiment D. Caged plants					
Number of hills	4	4	8	4	2
" " eggs	4100	4405	8505	4190	0
" " larvae recovered					
In upper parts of stalk	411	370	781	350	28
" lower " " "	329	448	777	441	20
" ears	374	501	875	454	11
Total	1114	1319	2433	1245	59
Per cent of recovered larvae in ears	34	38	36	36	19
" " " larval establishment	27	30	29	30	--

(Table 10 continued)

	Oviposition on stalk foliage			Oviposition on ear foliage	Check no oviposition recorded
	Upper	Lower	Total		
Experiment E. Exposed plants					
Number of hills	2	2	4	2	0
" " eggs	2195	2225	4420	2000	--
" " larvae recovered					
In upper parts of stalk	181	174	355	112	--
" lower " " "	225	192	417	252	--
" ears	195	314	509	376	--
Total	601	680	1281	740	--
Per cent of recovered larvae in ears	32	46	40	51	--
" " " larval establishment	27	31	29	37	--

[1] Experiments A and B were done on Early Crosby sweet corn at the Medford experiment field in 1927. Experiment C was done on Golden Bantam sweet corn at the Waltham experiment field in 1928, and included both artificial and natural oviposition. Experiments D and E were on Golden Bantam sweet corn at the Waltham experiment field in 1929. In experiment A the plants were grouped according to the natural oviposition found on them, and often plants representing two or more groups occurred in the same hills, hence, this experiment was subject to the greatest of interference by migration. This experiment contained another group, plants upon which eggs were found on both stalk and ear foliage, which is not included in the tabulation. The figures for this group are 8 plants, 388 eggs, 12 larvae recovered in stalks, 17 larvae recovered in the ears, a total of 29, average larvae per plant 4.1, per cent of recovered larvae in the ears 52, and per cent of larval establishment 7. In experiment B the artificially induced oviposition is recorded; no record was made of natural oviposition which probably interfered with the experiment. In experiment C the hills were caged

(Table 10 continued)

	Oviposition on stalk foliage			Oviposition on ear foliage	Check no oviposition recorded
	Upper	Lower	Total		
Experiment E. Exposed plants					
Number of hills	2	2	4	2	0
" " eggs	2195	2225	4420	2000	--
" " larvae recovered					
In upper parts of stalk	181	174	355	112	--
" lower " " "	225	192	417	252	--
" ears	195	314	509	276	--
Total	601	680	1281	740	--
Per cent of recovered larvae in ears	32	46	40	51	--
" " " larval establishment	27	31	29	37	--

1 Experiments A and B were done on Early Crosby sweet corn at the Medford experiment field in 1927. Experiment C was done on Golden Bantam sweet corn at the Waltham experiment field in 1928, and included both artificial and natural oviposition. Experiments D and E were on Golden Bantam sweet corn at the Waltham experiment field in 1929. In experiment A the plants were grouped according to the natural oviposition found on them, and often plants representing two or more groups occurred in the same hills, hence, this experiment was subject to the greatest of interference by migration. This experiment contained another group, plants upon which eggs were found on both stalk and ear foliage, which is not included in the tabulation. The figures for this group are 8 plants, 388 eggs, 12 larvae recovered in stalks, 17 larvae recovered in the ears, a total of 29, average larvae per plant 4.1, per cent of recovered larvae in the ears 52, and per cent of larval establishment 7. In experiment B the artificially induced oviposition is recorded; no record was made of natural oviposition which probably interfered with the experiment. In experiment C the hills were caged

(Table /0 continued)

to prevent natural oviposition, and in experiment D, which was planned merely as a check on C, the hills were left exposed. In all this work the dissections were made a short time after invasion of the plant had taken place.

2 The term artificial oviposition here refers to the obtaining of eggs on the foliage by caging moths on the plants.

Table 11 Larval establishment records

Location	Kinds of corn: Type	Kinds of corn: Variety	Plants examined	Egg masses found	Total eggs	Borers found	Average eggs per plant	Plants infested	Larval establishment
			#	#	#	#	#	%	%
First generation 1926									
Medford exp. field	Sweet	G. B.	200	43	792	392	4.0	64	49
" " "	Flint	Sanford	200	43	689	288	3.4	56	42
" farm	Sweet		100	77	1402	388	14.0	77	28
Waltham exp. field	"	G. B.	300	163	2698	560	9.0	69	21
" " "	"	S. E.	300	69	1264	340	4.2	41	27
" " "	Dent	N. W.	300	119	1900	450	6.3	64	24
Second generation 1926									
Medford exp. field	Sweet	G. B.	100	39	666	423	6.7	--	64
" " "	Dent	B. Y.	100	49	872	142	8.7	73	16
Waltham exp. field	Sweet	G. B.	50	20	435	133	8.7	51	31
" " "	Flint	Longf.	50	17	234	49	4.7	39	21
" " "	Dent	N. W.	50	11	194	67	3.9	63	35
First generation 1927									
Medford exp. field	Sweet	E. C.	100	7	120	44	1.2	--	37
" " "	"	E. C.	100	195[3]	4348	291	43.5	100	7
" " "	Flint	Longf.	100	236[3]	5208	316	52.1	100	6
" " "	Dent	B. Y.	100	190[3]	3890	78	38.9	100	2
Waltham exp. field	Sweet	G. B.	75	13	187	98	2.5	35	52
" " "	Sweet	G. B.	470	40	569	226	1.2	32	40

(Table // continued)

Location	Kinds of corn: Type	Kinds of corn: Variety	Plants examined #	Egg masses found #	Total eggs #	Borers found #	Average eggs per plant #	Plants infested %	Larval establishment %
			Second generation 1927						
Medford exp. field	Sweet	E. C.	50	61	1102	209	22.0	--	19
" " "	Flint	Longf.	50	15	279	53	5.6	77	19
" " "	Dent	B. Y.	50	36	647	26	12.9	87	4
Waltham exp. field	Flint	Longf.	75	72	1042	323	13.9	92	31
" " "	Dent	N. W.	75	8	132	63	1.8	41	48
			First generation 1928						
Waltham exp. field	Sweet	G. B.	225	25	298	104	1.3	51	35
" " "	Flint	E. Y. C.	225	54	763	246	3.4	74	32
" " "	Dent	P. N.	225	35	511	89	2.3	45	17
" " "	Sweet	E. C.	93[4]	202[3]	4610	224	49.6	100	5
" " "	Flint	E. Y.C.	88[4]	180[3]	5115	137	58.1	100	3
" " "	Dent	P. N.	61[4]	175[3]	4905	220	80.4	100	4
			Second generation 1928						
Waltham exp. field	Sweet	G. B.	150	105	2024	847	13.5	76	42
" " "	Dent	P. N.	150	188	2387	980	15.9	99	41
			First generation 1929						
Waltham exp. field	Sweet	G. B.	80	18	292	174	3.7	45	60
" " "	"	E. C.	80	29	589	194	7.4	70	33
" " "	Flint	E.Y.C.	80	24	392	213	4.9	60	54
" " "	Dent	N. W.	80	22	447	124	5.6	60	28
" " "	"	P. N.	80	11	237	124	3.0	45	52
			Second generation 1929						
Waltham exp. field	Sweet	G. B.	80	80	1434	677	17.9	100	47
" " "	Dent	P. N.	80	83	1495	559	18.7	100	37

(Table // continued)

[1] In all larval establishment work eggs were actually counted, not estimated by multiplying the number of masses by a mean number derived from previous records. In most of these experiments the plants were looked over three or four times during the oviposition season for eggs.

[2] G. B. stands for Golden Bantam, N. W. for Northwestern, S. E. for Stowell's Evergreen, B. Y. for Brewer's Yellow, Longf. for Longfellow, E. C. for Early Crosby, E. Y. C. for Early Yellow Canada, and P. N. for Pride of the North.

[3] This was artificially induced oviposition for a study of indirect injury.

[4] These three were planned as 100 plant series, but poor germination made this impossible.

[1] In all larval establishment work eggs were actually counted, not estimated by multiplying the number of masses by a mean number derived from previous records. In most of these experiments the plants were looked over three or four times during the oviposition season for eggs.

[2] G. B. stands for Golden Bantam, N. W. for Northwestern, S. E. for Stowell's Evergreen, B. Y. for Brewer's Yellow, Longf. for Longfellow, E. C. for Early Crosby, E. Y. C. for Early Yellow Canada, and P. N. for Pride of the North.

[3] This was artificially induced oviposition for a study of indirect injury.

[4] These three were planned as 100 plant series, but poor germination made this impossible.

Table 12 Survival through the egg stage compared with "5th instar" establishment

Type and variety of corn		Year	Generation	Eggs laid	Eggs hatched		5th instar larvae and pupae[1]	
				#	#	%	#	%
Golden Bantam	sweet	1926	first	2698	2232	83	560	21
Stowell's Evergreen	"	"	"	1264	1126	89	340	27
Northwestern	dent	"	"	1900	1784	94	450	24
Golden Bantam	sweet	1927	"	187	126	67	98	52
Longfellow	flint	"	second	1042	484	46	323	31
Northwestern	dent	"	"	132	120	91	63	48
Golden Bantam	sweet	1928	first	298	279	94	104	35
Early Canada	flint	"	"	763	641	84	246	32
Pride of the North	dent	"	"	511	429	84	89	17
Pride of the North	"	"	second	2387	1834	77	980	41
Total first generation		----	first	7621	6617	87	1887	25
Total second generation		----	second	3561	2438[2]	68	1366	38

1 The per cent of establishment is based on the total eggs laid.

2 This represents only 3 of the 10 plots here considered; actually the number of second generation eggs is much larger than the number of first generation eggs.

This work was all done at the Waltham experiment field.

Table 13 The effect of larval concentration on larval establishment

Group	Larvae set	Aver. days to dissection	Larvae recovered: In tassel buds	Larvae recovered: In foliage, etc.	Larvae recovered: Total	Larval establishment
	#	#	#	#	#	%
1	37	8	12	3	15	38
2	75	8	27	8	35	47
3	160	8	63	7	70	44
4	306	9	73	44	117	38
5	600	7	111	50	161	27
6	1000	7	177	196	373	37
Total	2178	8	463	308	771	35

Each group in this experiment represents 3 hills of 4 plants each, except the last group which contained only 2 hills; the average larvae per hill is 12, 25, 53, 102, 200, 500, that is, approximately double in each succeeding group. The plants used were Golden Bantam sweet corn, 6 to 8 inches high at the time of setting the newly-hatched larvae ~~in~~ on them. The larvae were placed on the plants July 17 to 21 and dissections made about a week later. This work was done at the Waltham experiment field in 1928.

Table 13 The effect of larval concentration on larval establishment

Group	Larvae set	Aver. days to dissection	Larvae recovered: In tassel buds	Larvae recovered: In foliage, etc.	Larvae recovered: Total	Larval establishment
	#	#	#	#	#	%
1	37	8	12	3	15	38
2	75	8	27	8	35	47
3	160	8	63	7	70	44
4	308	9	73	44	117	38
5	600	7	111	50	161	27
6	1000	7	177	196	373	37
Total	2178	8	463	308	771	35

Each group in this experiment represents 3 hills of 4 plants each, except the last group which contained only 2 hills; the average larvae per hill is 12, 25, 53, 102, 200, 500, that is, approximately double in each succeeding group. The plants used were Golden Bantam sweet corn, 6 to 8 inches high at the time of setting the newly-hatched larvae ~~in~~ on them. The larvae were placed on the plants July 17 to 21 and dissections made about a week later. This work was done at the Waltham experiment field in 1928.

Table 14 Larval establishment in ears versus stalks[1]

Experiment A. Establishment in nodes of stalk

Group	Larvae set	Days to dissection	Borers recovered: In leaf	Borers recovered: In stem	Borers recovered: Total	Larval establishment
	#	#	#	#	#	%
1	43	3	28	0	28	65
2	75	6	22	0	22	36
3	70	10	7	0	7	10
4	70	15	7	4	11	16
5	38	21	2	7	9	24
6	77	30	0	5	5	7
Total	373	--	66	16	82	22

Experiment B. Establishment in ears

Group	Larvae set	Days to dissection	Borers recovered: In silk	Borers recovered: In sheath	Borers recovered: In ear	Total	Larval establishment
	#	#	#	#	#	#	%
1	75	3	40	13	0	53	71
2	87	6	34	17	0	51	59
3	70	10	21	16	0	37	53
4	67	15	22	13	14	49	73
5	45	21	5	6	11	19	49
6	92	28	4	9	9	22	24
Total	436	--	126	74	34	231	53

(Table 14 continued)

1
In these experiments an attempt was made to isolate the nodes and the ears by the use of strips of tangle-foot paper. In the case of a node the leaf was cut off about 6 inches from the stem and a strip of tangle-foot paper wrapped around the stem above the node, and another below so that a leaf sheath was included. In the case of the ear the tangle-foot band was wrapped around the lower part of the ear. Newly-hatched larvae were placed on the leaf or the ear respectively. These barriers were probably only partially successful in keeping migrant larvae out and probably of little use in keeping the "set" larvae in, as much of the transference of larvae is through the air rather than by crawling on the plant surface.

Each group in experiment A represents two separate internodes, and each group in experiment B represents two ears.

(Table 14 continued)

1

In these experiments an attempt was made to isolate the nodes and the ears by the use of strips of tangle-foot paper. In the case of a node the leaf was cut off about 6 inches from the stem and a strip of tangle-foot paper wrapped around the stem above the node, and another below so that a leaf sheath was included. In the case of the ear the tangle-foot band was wrapped around the lower part of the ear. Newly-hatched larvae were placed on the leaf or the ear respectively. These barriers were probably only partially successful in keeping migrant larvae out and probably of little use in keeping the "set" larvae in, as much of the transference of larvae is through the air rather than by crawling on the plant surface.

Each group in experiment A represents two separate internodes, and each group in experiment B represents two ears.

Table 15 Migration of larvae from plants upon which eggs have hatched

to the other plants of the same hills.

First generation

Plot #	Plants upon which eggs hatched: Total plants	Total eggs	Plants with leaf injury	Plants with stalk injury	Larvae	Remaining plants of same hills: Total plants	Plants with leaf injury	Plants with stalk injury	Larvae
Golden Bantam sweet corn									
A 1	9	84	5	4	6	18	9	10	7
B 1	10	139	9	9	24	12	8	9	11
C 1	6	75	6	5	12	9	7	8	22
Total	25	298	20	18	42	39	24	27	40
Per cent			80	72			62	69	
Aver. per plant		11.9			1.7				1.0
Early Canada flint corn									
A 1	17	284	12	15	32	24	13	17	26
B 1	9	162	8	8	19	18	13	16	23
C 1	18	317	17	18	30	22	16	20	34
Total	44	763	37	41	81	64	42	53	83
Per cent			84	93			66	83	
Aver. per plant		17.3			1.8				1.3

(Table 15 continued)

Plot #	Plants upon which eggs hatched: Total plants	Total eggs	Plants with leaf injury	Plants with stalk injury	Larvae	Remaining plants of same hills: Total plants	Plants with leaf injury	Plants with stalk injury	Larvae
			Pride of the North dent corn						
A 1	5	108	5	3	1	13	11	9	7
B 1	10	184	5	6	5	18	5	12	12
C 1	10	219	9	8	15	22	17	21	21
Total	25	511	19	17	21	53	33	42	40
Per cent			76	68			62	79	
Aver. per plant		20.4			0.84				0.75
			Total first generation						
Total	94	1572	76	76	144	156	99	122	163
Per cent			84	84			63	78	
Aver. per plant		17.2			1.6				1.0

Second generation

Plot #	Plants upon which eggs hatched: # plants	# larvae	Remaining plants of same hills: # plants	# larvae
	Pride of the North dent corn			
A 1	10	45	11	57
B 1	19	97	14	64
C 1	14	184	18	177
Total	43	326	43	298
Average		7.6		6.9

This work was done in conjunction with that presented in table 16.

For further information see footnote of that table.

Table 16 Migration of larvae from hills upon which eggs have hatched to the remaining hills of the experiment[1]

First generation

Plot	Hills upon which eggs hatched: Total number, Hills	Total number, Plants	# showing leaf feeding, Hills	# showing leaf feeding, Plants	# showing stalk injury, Hills	# showing stalk injury, Plants	# larvae found	Hills upon which no eggs hatched: Total number, Hills	Total number, Plants	# showing leaf feeding, Hills	# showing leaf feeding, Plants	# showing stalk injury, Hills	# showing stalk injury, Plants	# larvae found
Golden Bantam sweet corn														
A 1	8	27	6	14	7	14	13	17	48	6	8	7	18	10
B 1	7	22	7	17	7	18	35	19	53	7	12	4	5	2
C 1	5	15	5	6	5	13	32	20	60	7	15	5	7	11
Total	20	64	18	37	19	45	80	56	161	20	35	16	30	23
Per cent			90	58	95	70				36	22	29	19	
Aver. per hill							4							0.4
Early Canada flint corn														
A 1	13	41	12	27	12	31	62	12	35	11	24	11	24	24
B 1	8	27	8	21	8	24	42	17	48	15	27	13	25	35
C 1	13	40	12	33	13	38	65	12	35	8	11	6	13	19
Total	34	108	32	81	33	93	169	41	118	34	62	30	62	78
Per cent			94	75	97	86				83	53	73	53	
Aver. per hill							5							1.9

(Table 16 continued)

Plot	Hills upon which eggs hatched							Hills upon which no eggs hatched						
	Total number		# showing leaf feeding		# showing stalk injury		# larvae found	Total number		# showing leaf feeding		# showing stalk injury		# larvae found
	Hills	Plants	Hills	Plants	Hills	Plants		Hills	Plants	Hills	Plants	Hills	Plants	
Pride of the North dent corn														
A 1	5	18	5	16	5	12	8	20	57	13	26	13	19	7
B 1	8	24	3	10	8	18	17	17	51	8	10	8	13	7
C 1	10	32	10	26	10	28	36	15	43	6	11	9	16	14
Total	23	74	18	52	23	58	61	52	151	27	47	30	48	28
Per cent			78	70	100	78				52	31	58	32	
Average per hill							2.7							0.54
Total of first generation														
Total	77	246	68	170	75	196	310	149	430	81	144	76	140	129
Per cent			88	69	97	80				54	34	51	33	
Average per hill							4.0							0.87

(Table 16 continued)

Second generation

Pride of the North dent corn

Plot #	Hills upon which eggs hatched: # hills	Hills upon which eggs hatched: # larvae	Hills upon which no eggs hatched: # hills	Hills upon which no eggs hatched: # larvae
A 1	16	188	9	49
B 1	16	210	9	19
C 1	22	491	3	20
Total	54	889	21	88
Average		16.5		4.2

[1] This work was done in conjunction with the natural larval establishment experiments carried on in 1928 at the Waltham experiment field. The number of hatched eggs were, for the first generation, Golden Bantam 279, Early Canada 641, and Pride of the North dent corn 511, and for the second generation 1834. See tables 11 and 12. The 25 hills of each variety used for this work formed a square in the middle of a larger plot of corn in each case; this was done in order to make the experiment serve for a study of migration as well as of larval establishment. The corn was all planted April 26.

[2] It was originally planned to do this work on the three types for both generations, but sufficient time could not be given to make all the second generation records.

Table 17 Migration of borers to adjacent rows[1]

	Early Crosby sweet corn	Early Canada flint corn	Pride of the North dent corn
Total number of eggs laid	590	1035	1005
Average # eggs per hill in artificially infested (center) row	59	104	101
Average # borers per hill in artificially infested (center) row	3	4.3	7.1
Average # borers per hill in adjacent rows	1.4	2.5	3.5
Average # borers per hill in remaining (outside) rows	1.2	2.5	1.7
Average # borers per hill in check plots[2]	0.9	1.4	2.1

[1] The plots in this experiment were square, consisting of 25 hills planted 3.5 feet apart; that is, there were 5 rows of 5 hills in each direction. In each case, except the check plots, the central row was artificially infested; ~~and~~ the row on either side of this was termed adjacent, and the outside rows were called the remaining rows. There were three plots in each variety; in the first, oviposition was obtained in the central row running east and west; the second was used as a check plot; and in the third, oviposition was obtained on the central north-south row. Waltham experiment field, 1927.

[2] This experiment was subject to a slight amount of natural oviposition, which would account for the borers in the check plots. Migration may have extended to the checks although precautions were taken to prevent this by isolating the plots with wide strips of plowed ground.

Table 18 Distance of borer migration [1]

	Groups [2] 1	2	3	4	5	Total
	Golden Bantam sweet corn					
Number of larvae recovered	8	19	34	34	87	182
" " hills	4	12	20	28	36	100
Average larvae per hill	2	1.6	1.7	1.2	2.4	1.8
	Early Canada flint corn					
Number of larvae recovered	2	1	4	6	18	31
" " hills	4	12	20	28	36	100
Average larvae per hill	0.5	0.1	0.2	0.2	0.5	0.3
	Pride of the North dent corn					
Number of larvae recovered	1	11	13	31	50	106
" " hills	4	12	20	28	36	100
Average larvae per hill	0.3	0.9	0.7	1.1	1.4	1.0

1 This experiment was done on small plants which had escaped the first generation natural infestation. Each variety of corn was planted in a square block of 100 hills, 10 on a side, and the 4 central hills were infested with 1000 newly-hatched larvae on July 16, 1929. Dissections for larval recoveries were made late in August.

2 Group number 1 represents the 4 central artificially infested hills; the succeeding groups represents the concentric rectangles of hills, surrounding this center group, the fifth group being the outside hills of the plot.

Table 8 Distance of borer migration [1]

	Groups [2] 1	2	3	4	5	Total
			Golden Bantam sweet corn			
Number of larvae recovered	8	19	34	34	87	182
" " hills	4	12	20	28	36	100
Average larvae per hill	2	1.6	1.7	1.2	2.4	1.8
			Early Canada flint corn			
Number of larvae recovered	2	1	4	6	18	31
" " hills	4	12	20	28	36	100
Average larvae per hill	0.5	0.1	0.2	0.2	0.5	0.3
			Pride of the North dent corn			
Number of larvae recovered	1	11	13	31	50	106
" " hills	4	12	20	28	36	100
Average larvae per hill	0.3	0.9	0.7	1.1	1.4	1.0

[1] This experiment was done on small plants which had escaped the first generation natural infestation. Each variety of corn was planted in a square block of 100 hills, 10 on a side, and the 4 central hills were infested with 1000 newly-hatched larvae on July 16, 1929. Dissections for larval recoveries were made late in August.

[2] Group number 1 represents the 4 central artificially infested hills; the succeeding groups represents the concentric rectangles of hills, surrounding this center group, the fifth group being the outside hills of the plot.

Table 19 Comparative larval migration on two dates

	Artificially infested hills	Surrounding hills	Total hills
Experiment A. Plants dissected 5 days after setting larvae			
Number of hills	5	16	21
" " newly-hatched larvae set	500	0	500
" " larvae recovered	90	16	106
Per cent of total larvae recovered	85	15	100
" " " larval establishment	18	3	21
Experiment B. Plants dissected 20 days after setting larvae			
Number of hills	5	16	21
" " newly-hatched larvae set	500	0	500
" " larvae recovered	24	11	35
Per cent of total larvae recovered	69	31	100
" " " larval establishment	5	2	7

These experiments were carried on at the Waltham experiment field in 1929 on Golden Bantam sweet corn. Each experiment was conducted on a rectangular plot of corn 7 hills long and 3 rows wide. The 5 artificially infested (inner) hills were thinned to one plant each in order to make migration more likely. These plants were 12 inches high when the larvae were set. In experiment A the larvae were set July 17 and dissections made July 22 and in experiment B the larvae were set July 18 and the dissections made August 7. This work, therefore, was done between the two generations and so would not be seriously effected by natural infestation.

Table 20 Parts of plant attacked by the larval instars of the first generation

Parts of plant	Larval instars 1	2	3	4	5	Pupae	Total
Group A. 5 hills totaling 29 stalks, aver. height 3.25 ft. Dissected July 12, 1929							
On green leaves	1	8	1				10
" pale "	19	49	14				82
" leaf-rib	2	5	3				10
In leaf-sheaths	3	18	8				29
" tassel-buds	2	15	15				32
" stem		2	2				4
Total	27	97	43				167
Group B. 9 hills totaling 43 stalks, aver. height 5.5 ft. Dissected July 26, 1929.							
On green leaves				2	2	3	7
" pale "			3	3		1	7
In leaf-ribs							0
" leaf-sheaths			2	1	6	2	11
" tassel-buds			3				3
" stems			8	25	90	8	131
" ear-silk		1	4	1	4		10
" ear-sheaths			8	3	11	1	23
" ear-shank			1	1	2		4
" kernels			1				1
Total		1	30	36	115	15	197

This work was done on Golden Bantam sweet corn in 1929 at the Waltham experiment field.

Table 20 Parts of plant attacked by the larval instars of the first generation

Parts of plant	Larval instars 1	2	3	4	5	Pupae	Total
Group A. 5 hills totaling 29 stalks, aver. height 3.25 ft. Dissected July 12, 1929							
On green leaves	1	8	1				10
" pale "	19	49	14				82
" leaf-rib	2	5	3				10
In leaf-sheaths	3	18	8				29
" tassel-buds	2	15	15				32
" stem		2	2				4
Total	27	97	43				167
Group B. 9 hills totaling 43 stalks, aver. height 5.5 ft. Dissected July 26, 1929.							
On green leaves				2	2	3	7
" pale "			3	3		1	7
In leaf-ribs							0
" leaf-sheaths			2	1	6	2	11
" tassel-buds			3				3
" stems			8	25	90	8	131
" ear-silk		1	4	1	4		10
" ear-sheaths			8	3	11	1	23
" ear-shank			1	1	2		4
" kernels			1				1
Total		1	30	36	115	15	197

This work was done on Golden Bantam sweet corn in 1929 at the Waltham experiment field.

Table 21 Parts of the plant infested at harvest time[1]

Planting date	Harvest date	Plants exam.[2]	Ears present	Plant infested[3] in stalk	in tassel stem	in suckers[4]	in ears	anywhere
		#	#	#	#	#	#	#
				Golden Bantam sweet corn				
April 26	August 20	150	159	52	19	12	9	63
May 9	" 22	150	145	21	5	7	11	35
" 25	" 24	150	157	40	8	7	16	58
June 6	Sept. 1	150	168	63	6	15	74	114
" 20	" 8	150	155	113	25	55	125	149
Total		750	784	289	63	96	235	419
				Black Mexican sweet corn				
April 26	August 24	150	157	47	19	11	11	63
May 25	" 30	150	154	62	11	34	72	116
June ~~25~~ 20	Sept. 14	150	141	146	40	85	118	150
Total		450	452	255	70	130	201	329
				Stowell's Evergreen sweet corn				
April 26	Sept. 4	150	145	81	13	54	86	136
May 25	" 11	150	149	144	13	74	127	150
Total		300	294	225	26	128	213	286
				Early Yellow Canada flint corn				
April 26	Oct. 11	150	136	144	42	59	100	147
May 25	" 15	150	129	150	30	89	107	150
Total		300	265	294	72	148	207	297

(Table 21 continued)

Planting date	Harvest date	Plants exam.[2]	Ears present	Plant infested[3] in stalk	in tassel stem	in suckers[4]	in ears	anywhere
		#	#	#	#	#	#	#
			Northwestern dent corn					
April 26	Oct. 9	150	[5]	145	56	4	--	150
May 25	" 10	150	119	146	31	5	102	149
June 20	" 10	150	119	150	64	21	117	150
Total		450		441	151	30	219	449
			Pride of the North dent corn					
April 26	Oct. 16	150	119	148	44	7	92	149
May 25	" 17	150	118	150	73	11	101	150
Total		300	237	298	117	18	193	299
			Golden Queen pop corn					
April 26	Oct. 17	150	178	150	65	30	126	150

1 These data were taken in conjunction with the work on effect of planting date. This work was done at the experiment field at Waltham, Mass. at the time when the ears were being harvested (the roasting stage for sweet corn, and the hard grain for the other types of corn) in the season of 1928. Both generations are involved, but for the most part, the early plantings of sweet corn show first generation, and the late plantings second generation infestation; the field corn was subject to both. Each entry represents a triplicate planting.

2 Fifty plants in each plot, that is 150 plants in each triplicate planting, were examined.

3 The tassel bud injury was recorded separately in the original data, but only 6 plants showing such injury were reported.

4 Unfortunately no record was kept of the total number of suckers present on the examined plants. Such a record was kept for the plant dissections and is shown in table 22 .

(Table 21 continued)

5 Counts were not made of the ears in the first planting of Northwestern dent because of the damage to the ears by birds.

Table 22 Number of larvae in different parts of the plant [1]

Planting date	Harvest date	Plants dissected [2]	Suckers present	Ears present	Larvae found in Stalk	Suckers	Ears	Total
		#	#	#	#	#	#	#
			Golden Bantam sweet corn					
April 26	August 20	30	43	34	31	14	7	52
May 9	" 22	30	54	30	33	21	3	57
May 25	" 24	30	36	33	45	10	20	75
June 6	" 31	30	41	35	90	45	84	219
" 20	Sept. 8	30	53	37	130	104	137	371
Total		150	227	169	329	194	251	774
			Black Mexican sweet corn					
April 26	August 24	30	45	36	41	8	12	61
May 25	" 30	30	30	35	59	25	60	144
June 20	Sept. 14	30	45	33	366	161	191	718
Total		90	120	104	466	194	263	923
			Stowell's Evergreen sweet corn					
April 26	Sept. 4	30	31	33	185	130	168	483
May 25	" 11	30	31	33	284	139	170	593
Total		60	61	66	469	269	338	1076
			Early Yellow Canada flint corn					
April 26	Oct. 11	30	12	32	144	35	52	231
May 25	" 15	30	15	31	255	78	91	424
Total		60	27	63	399	113	143	655

(Table 22 continued)

Planting date	Harvest date	Plants dissected[2]	Suckers present	Ears present	Larvae found in Stalk	Suckers	Ears	Total
		#	#	#	#	#	#	#
				Northwestern dent corn				
April 26	Oct. 9	30	3	0	133	0	0	133
May 25	" 10	30	4	30	137	8	73	218
June 20	" 10	30	6	30	248	16	174	438
Total		90	13	60	518	24	247	789
				Pride of the North dent corn				
April 26	Oct. 16	30	4	29	271	4	43	318
May 25	" 17	30	2	29	234	7	48	289
Total		60	6	58	505	11	91	607
				Golden Queen pop corn				
April 26	Oct. 17	30	7	42	302	38	49	389

1 See footnote 1, table 21.

2 Ten plants were dissected in each plot making a total of 30 for each of the triplicate series, ~~and 60 for each of the sextuple series. See footnote 2, table~~ .

Table 23 Number of larvae in different parts of the ear[1]

Planting date	Harvest date	Ears dissected[2]	Larvae found in silk	sheaths	cob	shank	grain	total
		#	#	#	#	#	#	#
			Golden Bantam sweet corn					
April 26	August 20	30	3	1	3	2	2	11
May 9	" 22	30	16	0	0	1	0	17
" 25	" 24	30	41	11	1	0	1	54
June 6	" 31	30	87	1	0	0	1	89
" 20	Sept. 8	30	58	14	1	2	9	84
Total		150	205	27	5	5	13	255
			Black Mexican sweet corn					
April 26	August 24	30	14	0	2	0	6	22
May 25	" 30	30	55	5	4	0	10	74
June 20	Sept. 14	30	40	50	2	4	27	123
Total		90	109	55	8	4	43	219
			Stowell's Evergreen sweet corn					
April 26	Sept. 4	30	51	18	1	0	18	88
May 25	" 11	30	33	58	2	5	22	120
Total		60	84	76	3	5	40	208
			Early Yellow Canada flint corn					
April 26	Oct. 11	30	0	10	13	23	13	59
May 25	" 15	30	0	11	14	47	23	95
Total		60	0	21	27	70	36	154

(Table 23 continued)

Planting date	Harvest date	Ears dissected[2]	Larvae found in silk	sheaths	cob	shank	grain	total
		#	#	#	#	#	#	#
				Northwestern dent corn				
Apr. 26[3]								
May 25	Oct. 10	30	1	6	17	28	35	87
June 20	" 10	30	0	19	49	71	47	186
Total		60	1	25	66	99	82	273
				Pride of the North dent corn				
Apr. 26	Oct. 16	30	0	6	13	29	9	57
May 25	" 17	30	0	5	17	29	7	58
Total		60	0	11	30	58	16	115
				Golden Queen pop corn				
Apr. 26	Oct. 17	30	4	5	13	17	2	41

1 See footnote 1, table 21 .

2 Ten ears dissected in each plot, making 30 in each triplicate series, ~~and 60 in each sectuple series. See footnote 2, table~~ .

3 Counts were not made of the ears in the first planting of Northwestern dent because of the damage to the ears by birds.

Table 24 Parts of plants infested late in September 1927[1]

Generation	Borers in plant exclusive of true ears: In stems	In leaves	In rudimentary ears[2]	Total	Borers in ears: In silk	In rest of ear	Total	Borers in whole plant
A. Longfellow flint corn (100 plants dissected)								
First	16	0	0	16	1	13	14	30
Second	69	15	17	101	12	48	60	161
B. Early Crosby sweet corn (100 plants dissected)								
First	21	0	8	29	7	11	18	47
Second	196	25	145	366	25	150	175	541
C. Golden Bantam sweet corn (100 plants dissected)								
First	7	0	6	13	0	15	15	28
Second	134	17	98	249	19	139	158	407
D. Total of the three varieties (300 plants dissected)								
First	44	0	14	58	8	39	47	105
Second	399	57	260	716	56	337	393	1109
Total	443	57	274	774	64	376	440	1214

[1] This work was done in late September at the Medford experiment field, on late planted corn, Longfellow planted May 23, Early Crosby June 20, and Golden Bantam June 21. It was, therefore, essentially second generation work; the few first generation larvae found were probably all migrants from earlier plantings of corn close-at-hand. Each group represents 100 infested plants dissected. The proportion of plants infested in each variety was Longfellow 70 %, Early Crosby 92 %, Golden Bantam 65 %.

[2] Rudimentary ears refers to those large enough to have ear foliage and silk, but no developed kernels. They average in number roughly about the same as developed ears, about 1 to a plant.

Table 25. Effect of plant injury on yield

	Condition of plants		
	Non- or lightly infested	Medium infested	Heavily infested
Number plants dissected	100	100	100
Number of ears on these plants	112	92	82
Number of nubbins on these plants	6	24	26
Number of ears and nubbins on these plants	118	116	108
Average number of ears per plant	1.1	0.9	0.8
Average number of ears and nubbins per plant	1.2	1.2	1.1
Total weight of ears and nubbins in ounces	716	616	513
Weight of ears and nubbins per plant	7.2	6.2	5.1
Average weight of ears and nubbins	6.1	5.3	4.8
Average length of ears and nubbins	5.8	5.0	4.8
Average diameter of ears and nubbins	1.66	1.64	1.56
Average number kernels per ear and nubbin	397	361	335
Average number of borers per plant	0.4	0.8	2.9
Indicated loss in number ears per plant		0.2	0.3
Indicated % loss in number ears per plant		18.2	27.3
Indicated loss in weight of ears and nubbins per plant		1.0	2.1
Indicated % loss in weight of ears and nubbins per plant		16.4	34.4
Indicated loss in average length of ears and nubbins		0.8	1.0
Indicated % loss in average length of ears and nubbins		13.8	17.2
Indicated loss in average volume of ears and nubbins		1.9	3.3
Indicated % loss in average volume of ears and nubbins		15.2	26.2
Indicated loss in average number of kernels per ear and nubbin		36	62
Indicated % loss in average number of kernels per ear and nubbin		9.1	15.6
Indicated % loss in weight per larva per plant		21.3	11.5
Average number larvae per lost ounce of ears and nubbins		0.8	1.4

This work was done at the Medford experiment field in 1927, on Early Crosby sweet corn. Seed was planted April 26, and infestation was obtained by inducing oviposition on the plants; the lightly infested group represented natural infestation.

	Non- or Lightly Infested	Medium Infested	He In
Number plants dissected	100	100	
Number of ears on these plants	112	92	
Number of nubbins on these plants	6	24	
Number of ears and nubbins on these plants	118	116	
Average number of ears per plant	1.1	0.9	
Average number of ears and nubbins per plant	1.2	1.2	
Total weight of ears and nubbins in ounces	720	616	
Weight of ears and nubbins per plant	7.2	6.2	
Average weight of ears and nubbins	6.1	5.3	
Average length of ears and nubbins	5.8	5.0	
Average diameter of ears and nubbins	1.66	1.64	
Average number kernels per ear and nubbin	397	361	
Average number of borers per plant	0.4	0.8	
Indicated loss in number ears per plant		0.2	
Indicated % loss in number ears per plant		18.2	
Indicated loss in weight of ears and nubbins per plant		1.0	
Indicated % loss in weight of ears and nubbins per plant		16.4	
Indicated loss in average length of ears and nubbins		0.8	
Indicated % loss in average length of ears and nubbins		13.8	
Indicated loss in average volume of ears and nubbins		1.9	
Indicated % loss in average volume of ears and nubbins		15.2	
Indicated loss in average number of kernels per ear and nubbin		36	
Indicated % loss in average number of kernels per ear and nubbin		9.1	
Indicated % loss in weight per larva per plant		21.3	
Average number larvae per lost ounce of ears and nubbins		0.8	

This work was done at the Medford experiment field in 1927 on Early Crosby sweet corn. Seed was planted April 26 and infestation was obtained by inducing oviposition on the plants; the lightly infested group represented natural infestation.

Fig. 1. Oviposition cage

Fig. 2. A larva in debris

Fig. 3. Pupae in stalk and ears of corn

Fig. 4. Pupa in a leaf fold

Fig. 5. Leaf-sheath cut away to show injury
on inner side

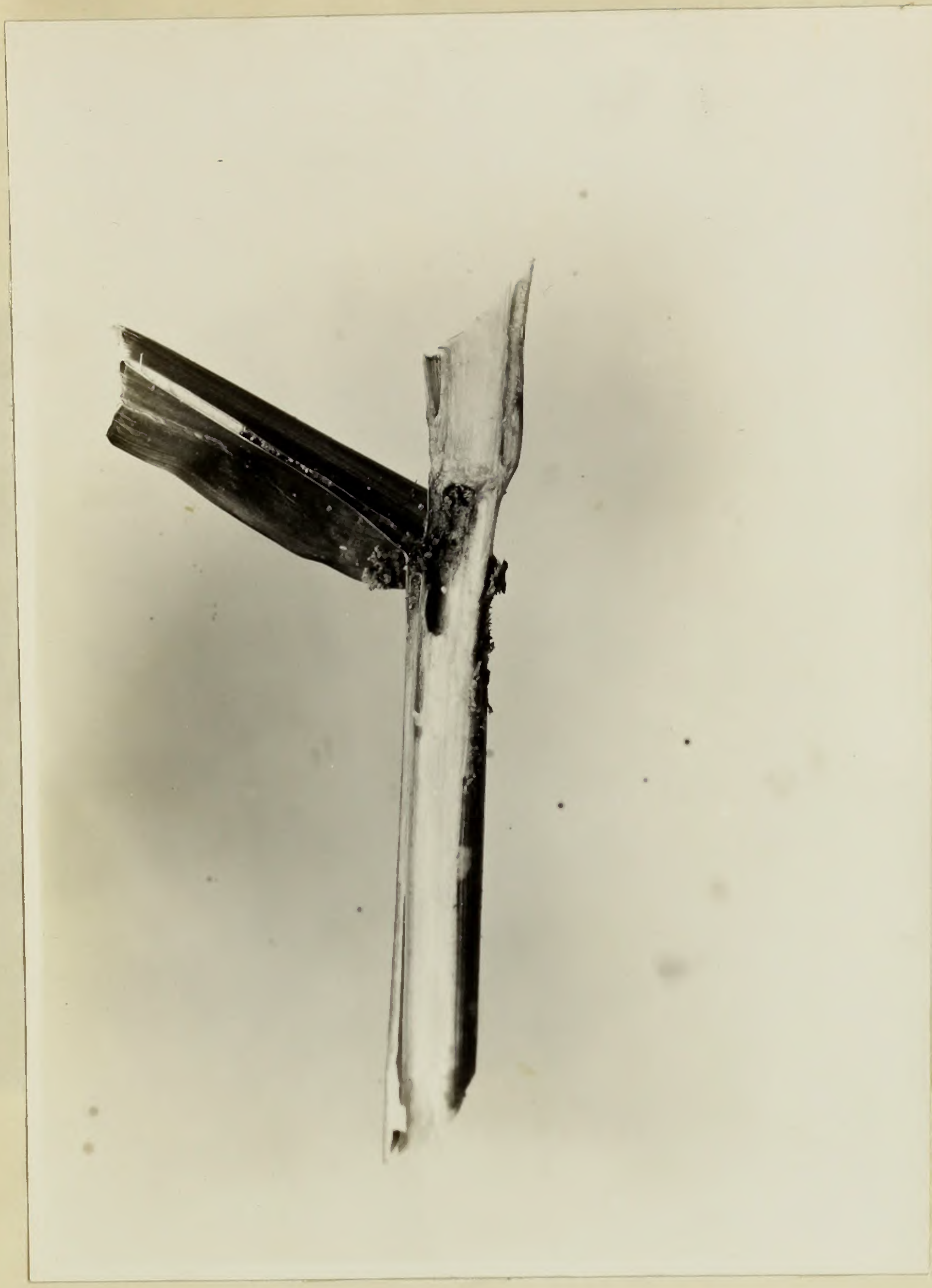

Fig. 6. Invasion of a plant via a leaf-rib

Fig. 7. Entering tunnels into stem of corn

Fig. 8. Early feeding areas on the leaf-blades

Fig. 9. Feeding area enlarged greatly

Fig. 10. Rows of holes through the leaves

Fig. 11. Broken-over tassel stem

Fig. 12. Infested flint corn plant showing extruded frass from stem and ear

Fig. 13. Badly infested plant partially sectioned to show condition of pith

Fig. 14. Typically infested ears of sweet corn